

## DESCRIPTION

## METHOD OF FORMING LAMINATED RESIST

5

## TECHNICAL FIELD

The present invention relates to a method of forming a laminated resist produced by forming an antireflection layer on a photoresist layer.

10

## BACKGROUND ART

In recent years, with the advance of high integration and high speed operation of LSI, scale down of design rule is demanded, and for that reason, reduction of wavelength of exposure light source used for forming a resist pattern has been progressing. In a mass  
15 production process of 64 M bit DRAM (dynamic random access memory), KrF excimer laser (248 nm) has been used, and in production of 256 M and 1G bit or more DRAM, ArF excimer laser (193 nm) having a shorter wavelength is used as an exposure light source. Recently aiming at further micro fabrication, F<sub>2</sub> (157 nm) laser having a further  
20 shorter wavelength is studied as a new exposure light source.

For an exposure system for those lithography processes, a combination of monochromatic light and dioptric system lens is mainly used. However since a standing wave is generated due to interference between the incident light and the reflection light from a substrate at  
25 the time of exposure, fluctuation in dimensions such as width of pattern line and breakage of pattern form arise. Particularly in the case of forming a fine resist pattern on a semiconductor substrate

having a step, such a dimensional fluctuation and breakage of pattern form due to a standing wave are significant (standing wave effect).

So far methods for reducing this standing wave effect have been proposed, such as a method of blending a light absorbing agent in a resist material, a method of providing an antireflection layer on a top surface of a resist layer (ARCOR method, JP60-38821A, JP62-62520A, JP62-62521A) and a method of providing an antireflection layer on a bottom surface of a resist (BARC method, JP62-159143A). Among those methods, the ARCOR method comprises a step for forming a transparent upper antireflection film layer on a top surface of a resist and peeling the film after exposure. In this method, a fine pattern having a high dimensional accuracy, particularly a high matching accuracy is formed by its easy film formation procedure.

In the BARC method, too, a high reflection reducing effect can be obtained, but in the case where a substrate has a step, there are disadvantages that a thickness of the antireflection film on the step fluctuates largely, thereby greatly changing a reflectance and the reflectance is increased if the antireflection film thickness is increased for reducing a film thickness fluctuation. Therefore a combination use of an upper antireflection film layer to be provided on the top surface of the photoresist layer is desired. The upper antireflection film layer has not only a primary function of reflection reduction but also a function of preventing a developing failure by enhancing affinity for a developing solution after the exposure or a function as a barrier film from environment, and therefore will be a more important material.

At the initial stage of development, perfluoropolyether

having a low refractive index was studied as an antireflection film material for the ARCOR method, but had demerits from the viewpoint of practical use because a fluorine-containing hydrocarbon solvent must be used as a diluent or a releasing agent, thereby resulting in a high cost and causing a problem with film forming property.

In order to overcome those demerits, fluorine-containing antireflection film materials which can be released easily with an aqueous alkali solution used as a developing solution or pure water used as a rinsing solution have been developed (JP5-188598A, JP6-41768A, JP6-51523A, JP7-234514A, JP8-305032A, JP8-292562A, JP11-349857A and JP11-352697A).

Those materials are mainly compositions of a water soluble polymer such as polyvinyl pyrrolidone or polyvinyl alcohol which is a non-fluorine-containing binder polymer; and a low molecular weight fluorine-containing alkylsulfonic acid, fluorine-containing alkylcarboxylic acid or amine salt thereof; or further a high molecular weight fluorine-containing polyether having sulfonic acid, carboxylic acid or amine salt thereof at an end of its trunk chain.

However when a low molecular weight fluorine-containing alkylsulfonic acid, fluorine-containing alkylcarboxylic acid or amine salt thereof is used, there is a disadvantage that diffusion thereof in a resist layer occurs because its molecular weight is low, and a pattern profile of a resist is deteriorated.

Also when a high molecular weight fluorine-containing polyether having sulfonic acid, carboxylic acid or amine salt thereof at an end of its trunk chain is used, there are disadvantages that in the case of a molecular weight being high enough for preventing the

diffusion, its water solubility is lowered or it becomes insoluble and also film forming property is lowered.

Further an antireflection film prepared by using, as a binder polymer, polyvinyl pyrrolidone developed for the use for KrF is not  
5 suitable as an antireflection film material for a ArF resist since polyvinyl pyrrolidone has a high refractive index at an exposure wavelength of ArF excimer laser and a low exposure light transmission.

On the other hand, in order to compensate for those demerits, compositions for an antireflection film prepared by using a  
10 fluorine-containing polymer having sulfonic acid or its amine salt in a side chain thereof (JP2001-194798A, JP2001-200019A) or by using a fluorinated alkylamine salt of carboxylic acid or a perfluoro compound having, as a counter ion, alkanolamine salt (JP2001-133984A) have been developed.

15 Among them, in the case of fluorine-containing antireflection film materials having sulfonic acid or amine salt thereof in its side chain (JP2001-194798A, JP2001-200019A), there are problems that since acidity of the sulfonic acid or amine salt thereof is too strong, a surface layer portion of a resist pattern is rounded after  
20 developing, thereby causing a problem in an etching step; a surface layer portion of an un-exposed portion also undergoes chemical amplification reaction, and a thickness of the un-exposed portion is decreased; and corrosion and rusting of equipment for producing devices arise due to an influence of an acid component, thereby  
25 causing defect of products.

On the other hand, in the case of fluorine-containing antireflection film materials prepared by using a perfluoro compound

having, as a counter ion, fluorinated alkanolamine salt or alkylamine salt of carboxylic acid (JP2001-133984A), a fluorine content is low and a refractive index being low enough for practical use cannot be obtained. Also there are disadvantages that due to a small amount of hydrophilic groups contained in the monomer, solubility (=dissolution rate) in a resist developing solution and an aqueous solvent is very low, and film forming property is not good.

Also compositions for an antireflection film prepared by using a fluorine-containing polymer having a high content of carboxyl groups are studied (JP11-124531A, JP2004-37887A), but only polymers having a low molecular weight are obtained as a fluorine-containing polymer having carboxyl groups, and studies are made with respect to compositions for an antireflection film for a resist prepared by using such low molecular weight fluorine-containing polymers.

Those low molecular weight fluorine-containing polymers are insufficient in solubility in water, and addition of amines or surfactants is necessary. As a result, there are problems that a refractive index of an antireflection film is decreased and transparency is lowered.

Further in order to make the polymers soluble, it is necessary to mix a large amount of a water soluble organic solvent such as alcohols to water, and as a result, there arises intermixing between the resist layer and the antireflection layer when coating on a resist film and a sufficient reflection reducing effect cannot be obtained.

Accordingly, the present situation is such that materials for

an upper antireflection film layer, particularly materials for an upper antireflection film layer for ArF and F<sub>2</sub> photoresists which eliminate the mentioned problems and have practical water solubility are desired.

As mentioned above, conventional polymers used for  
5 antireflection film materials are high in a refractive index, and a sufficient effect thereof in pattern formation could not be obtained.

On the other hand, conventional materials were insufficient in water solubility even if a refractive index thereof was low. Therefore when forming an antireflection film on a photoresist layer, it was  
10 necessary to use an organic solvent for a coating composition containing a polymer. As a result, there arose intermixing between the photoresist layer and the antireflection layer to make an interface between them unclear and effects resulting from a low refractive index could not be exhibited sufficiently. Also solubility in a developing  
15 solution (dissolution rate) was insufficient, and in a conventional developing process, the antireflection layer could not be removed and even in a step for removing a resist layer of exposed region in the developing process, there was a case where the antireflection layer could not be smoothly removed.

20 A problem to be solved in the present invention is to form a laminated resist which has a sufficient reflection reducing effect particularly in a photolithography process using light in a vacuum ultraviolet region by providing, on a photoresist layer, an antireflection film for a resist obtained from a fluorine-containing polymer having a  
25 lower refractive index and excellent solubility in a developing solution and also has sufficient developing characteristics even in a developing step of the photolithography process.

## DISCLOSURE OF INVENTION

The present inventors have made intensive studies with respect to various fluorine-containing polymers having hydrophilic group, and as a result, have found a fluorine-containing polymer being  
5 capable of exhibiting both of a low refractive index and solubility in water or a developing solution (aqueous solution of 2.38 % by mass of tetramethylammonium hydroxide) and also have found that by providing, on a photoresist layer, an antireflection layer obtained from this fluorine-containing polymer, good reflection reducing effect can be  
10 exhibited in an exposure process of photolithography and the antireflection layer can be easily removed in a developing process.

Namely, a method of forming a laminated photoresist of the present invention comprises:

- (I) a step for forming a photoresist layer (L1) on a substrate and
- 15 (II) a step for forming an antireflection layer (L2) on the photoresist layer (L1) by applying a coating composition containing a fluorine-containing polymer (A) having hydrophilic group Y, and the fluorine-containing polymer (A) has a structural unit derived from a fluorine-containing ethylenic monomer having hydrophilic group Y and  
20 is characterized in that:
  - (i) the hydrophilic group Y contains an acidic OH group having a pKa value of not more than 11,
  - (ii) a fluorine content is not less than 50 % by mass, and
  - (iii) the number of moles of the hydrophilic group Y in 100 g of the  
25 fluorine-containing polymer (A) is not less than 0.14.

## BRIEF DESCRIPTION OF DRAWING

Fig. 1 is a flow chart for explaining the method of forming the laminated photoresist of the present invention.

## 5 BEST MODE FOR CARRYING OUT THE INVENTION

First, the fluorine-containing polymer (A) constituting the antireflection layer (L2) in the method of forming the laminated photoresist of the present invention is explained below.

In the present invention, the fluorine-containing polymer (A)  
10 which is used for the antireflection layer (L2) has the hydrophilic group Y. This hydrophilic group Y is introduced as a part of a structural unit of the fluorine-containing polymer (A) by polymerizing a fluorine-containing ethylenic monomer having hydrophilic group Y.

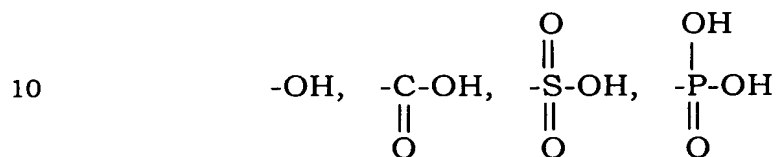
Namely, it is important for the fluorine-containing polymer  
15 to have a repeat unit (structural unit) of a fluorine-containing ethylenic monomer having hydrophilic group Y, thereby enabling particularly both of a low refractive index and water solubility or solubility in a developing solution (dissolution rate) to be exhibited and further enabling the obtained thin antireflection film layer to be endowed with  
20 a good mechanical strength as a self-supporting film.

It is particularly preferable that among the structural units constituting the fluorine-containing polymer (A), the structural unit having the hydrophilic group Y is substantially comprised of only a structural unit obtained by polymerizing a fluorine-containing  
25 ethylenic monomer having the hydrophilic group Y, thereby enabling a lower refractive index to be achieved while maintaining good water solubility or solubility in a developing solution (dissolution rate).



In the structural unit which is derived from a fluorine-containing ethylenic monomer having the hydrophilic group Y and constitutes the fluorine-containing polymer (A), the hydrophilic group Y contains an acidic OH group having a pKa value of not more than 11.

Examples of the hydrophilic group Y are concretely those having an acidic OH group such as:



and the like, and showing an acidity of not more than 11 of a pKa value.

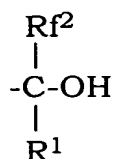
15                    Particularly preferred are -OH and -COOH from the viewpoint of excellent transparency and a low refractive index.

In the case of -SO<sub>3</sub>H and -P(=O)(OH)<sub>2</sub>, attention should be attracted to the points that when a film of a fluorine-containing polymer having such groups is formed on the photoresist layer (L1), depending on kind of the photoresist, there is a case where too high acid strength or acid diffusion has an adverse effect on a pattern profile and causes an excessive decrease of a thickness of an un-exposed portion.

25                    A pKa value of those acidic OH groups in the hydrophilic group Y is not more than 11, preferably not more than 10, more preferably not more than 9.

When the hydrophilic group Y is -OH group, in order to

adjust its acidity to be not more than 11 in a pKa value, it is preferable to bond a fluorine-containing alkyl group or a fluorine-containing alkylene group to the carbon atom directly bonded to the -OH group. Concretely it is preferable that the structural unit has a moiety  
5 represented by the following formula:



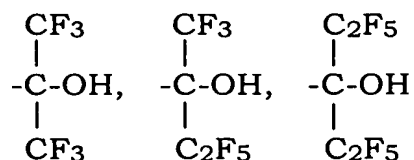
10

wherein Rf<sup>2</sup> is a fluorine-containing alkyl group which has 1 to 10 carbon atoms and may have ether bond; R<sup>1</sup> is at least one selected from the group consisting of H, a hydrocarbon group having 1 to 10 carbon atoms and a fluorine-containing alkyl group which has 1 to 10  
15 carbon atoms and may have ether bond.

It is particularly preferable that R<sup>1</sup> is a fluorine-containing alkyl group which has 1 to 10 carbon atoms and may have ether bond.

It is further preferable that both of Rf<sup>2</sup> and R<sup>1</sup> are perfluoroalkyl groups. Concretely preferred are moieties such as:

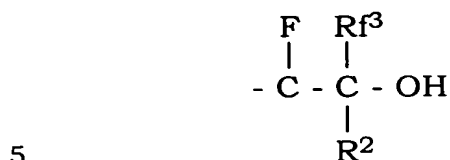
20



25 and the like.

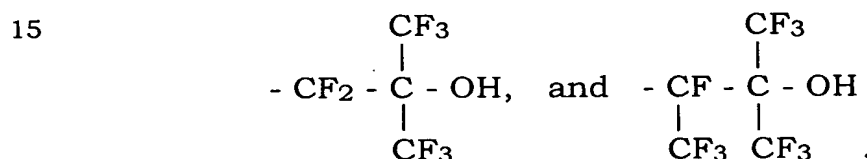
It is further preferable, from the viewpoint of water solubility and solubility in a developing solution, that the structural unit has a

moiety represented by the following formula:



wherein  $\text{Rf}^3$  is a fluorine-containing alkyl group which has 1 to 10 carbon atoms and may have ether bond;  $\text{R}^2$  is at least one selected from the group consisting of H, a hydrocarbon group having 1 to 10 carbon atoms and a fluorine-containing alkyl group which has 1 to 10 carbon atoms and may have ether bond.

Concretely preferred are structural units having moieties such as:



The acidic OH group in the above-mentioned moiety having -OH can have a pKa value of not more than 11 and is preferred.

The acidic OH group in -COOH can have a pKa value of not more than 11 irrespective of an ambient structure, and the pKa value is concretely not more than 6, more preferably not more than 5.

A lower limit of a pKa value of the acidic OH group in the hydrophilic group Y is 1, preferably 2, more preferably 3. If the pKa value is too low, depending on kind of the lower photoresist layer (L1), there is a case where too high acid strength or acid diffusion has an

adverse effect on a pattern profile and causes an excessive decrease of a thickness of an un-exposed portion.

Those exemplified hydrophilic groups having -OH group are preferred particularly because of excellent transparency and a low refractive index, and the hydrophilic groups having -COOH group are preferred particularly from the viewpoint of water solubility and solubility in a developing solution.

Particularly -COOH group is useful and preferred especially for an antireflection film in a ArF or KrF photolithography process since it is excellent in water solubility and solubility in a developing solution and has transparency at a wavelength of not less than 193 nm.

A fluorine content of the fluorine-containing polymer (A) used for the antireflection layer (L2) of the present invention is not less than 50 % by mass. When the fluorine content is less than 50 % by mass, in a photolithography process using light of not more than 200 nm in a vacuum ultraviolet region at exposing, a refractive index measured at such a wavelength becomes too high. As a result, a reflection reducing effect cannot be obtained sufficiently, and an effect of decreasing an adverse influence on a resist pattern due to a standing wave effect and a multiple reflection effect becomes insufficient.

The fluorine content of the fluorine-containing polymer (A) is preferably not less than 55 % by mass, more preferably not less than 57.5 % by mass, which is preferred since it is possible to obtain a refractive index, for example, at 193 nm of not more than 1.46, particularly not more than 1.44, further not more than 1.42.

An upper limit of the fluorine content is 70 % by mass, preferably 65 % by mass, more preferably 62.5 % by mass, especially 60 % by mass. If the fluorine content is too high, water repellency of the formed film becomes too high and there is a case where a  
5 dissolution rate in a developing solution is decreased and repeatability of the dissolution rate is lowered.

Further in the present invention, it is important to use, for the antireflection layer (L2), a fluorine-containing polymer having a specific content or more of hydrophilic group Y, namely, a  
10 fluorine-containing polymer having a hydrophilic group content higher than that of conventional polymers.

Concretely the number of moles of the hydrophilic group Y in 100 g of the fluorine-containing polymer (A) is not less than 0.14, which gives good water solubility and good solubility in a developing  
15 solution (dissolution rate) and enables the polymer to be put into practical use.

If the number of moles of the hydrophilic group Y in 100 g of the fluorine-containing polymer (A) is less than 0.14, the polymer becomes insoluble in water or in a developing solution, or even if the  
20 polymer dissolves in a developing solution, a dissolution rate at the developing process is low and practicability of the polymer in a photolithography process becomes insufficient.

The number of moles of the hydrophilic group Y in 100 g of the fluorine-containing polymer (A) is not less than 0.21, more  
25 preferably not less than 0.22.

An upper limit of the content (the number of moles) of hydrophilic group Y is 0.5, more preferably 0.45, further preferably 0.4

in 100 g of the fluorine-containing polymer (A). If the content of hydrophilic group Y is too high, there is a case where transparency in a vacuum ultraviolet region is lowered and a refractive index is increased.

5                    Particularly in the case that the hydrophilic group Y is carboxyl group (-COOH), if its content is increased too much, there is a high tendency that at a wavelength of 193 nm, transparency is lowered and a refractive index becomes worse (is increased). The number of moles of -COOH groups in 100 g of the polymer is preferably from 0.14  
10 to 0.40, more preferably from 0.21 to 0.29, particularly preferably from 0.22 to 0.28. When the content of -COOH groups is in the above-mentioned range, it is possible to achieve good water solubility, a low refractive index and good transparency of the fluorine-containing polymer.

15                    Also the present inventors have made studies regarding further enhancement of water solubility of the above-mentioned fluorine-containing polymer having high contents of -COOH group and fluorine, and as a result, have found that the fluorine-containing polymer having a specific number average molecular weight has good  
20 water solubility.

                    As a result, even in the case of dissolving the polymer in a solvent mixture of water and alcohol solvent, a mixing ratio of the alcohol solvent can be reduced, and it is possible to prevent lowering of a reflection reducing effect which arises due to intermixing at an  
25 interface when overcoating the coating composition on the resist film.

                    Further it was found out that when a composition is prepared by using water, water solubility can be maintained stably

when storing for a long period of time. Also it was found out that good solubility is exhibited in the case of adding an acidic substance, surfactant, organic solvent and other additives.

Namely, a number average molecular weight of the  
5 above-mentioned fluorine-containing polymer having -COOH group is from 10,000 to 750,000, preferably from 20,000 to 500,000, more preferably from 31,000 to 300,000, particularly preferably from 40,000 to 200,000.

If the number average molecular weight is too low, water  
10 solubility is lowered. Even if the polymer can be dissolved in water, stability of the aqueous solution becomes insufficient, and also the fluorine-containing polymer is partially subject to sedimentation, precipitation or turbidity in white during storing or by adding additives.

15 On the other hand, if the number average molecular weight is too high, film forming property of the antireflection film is lowered, which is not preferred.

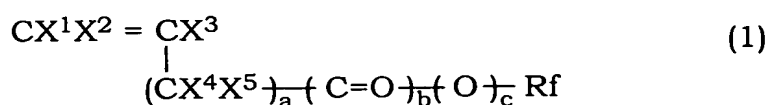
In the method of forming a laminated photoresist of the present invention, when the fluorine-containing polymer (A) satisfying  
20 the above-mentioned requirements with respect to kind (i) and content (iii) of the hydrophilic group Y and fluorine content (ii) is used for the antireflection layer (L2), the laminated photoresist can be practically applicable to conventional photoresist processes and can decrease an adverse effect on a resist pattern due to a standing wave effect and  
25 multiple reflection effect.

The first of the preferred examples of the fluorine-containing polymer (A) having hydrophilic group is a fluorine-containing polymer

represented by the formula (M-1):



- 5 wherein the structural unit M1 is a structural unit derived from a fluorine-containing monomer represented by the formula (1):



10

wherein  $X^1$  and  $X^2$  are the same or different and each is H or F;  $X^3$  is H, F, Cl,  $CH_3$  or  $CF_3$ ;  $X^4$  and  $X^5$  are the same or different and each is H or F; Rf is a monovalent organic group in which 1 to 4 hydrophilic groups Y are bonded to a fluorine-containing alkyl group having 1 to 40  
15 carbon atoms or a monovalent organic group in which 1 to 4 hydrophilic groups Y are bonded to a fluorine-containing alkyl group having 2 to 100 carbon atoms and ether bond; a, b and c are the same or different and each is 0 or 1,

the structural unit N1 is a structural unit derived from a monomer  
20 copolymerizable with the fluorine-containing monomer of the formula (1), and

the structural units M1 and N1 are contained in amounts of from 30 to 100 % by mole and from 0 to 70 % by mole, respectively.

The fluorine-containing monomer of the formula (1) is  
25 characterized by having a monovalent organic group Rf containing a fluorine-containing alkyl group in its side chain and having 1 to 4 hydrophilic groups Y bonded to the Rf group. Since the monomer



itself contains the hydrophilic groups Y and many fluorine atoms, a low refractive index, water solubility and solubility in a developing solution can be given to the polymer obtained from such a monomer.

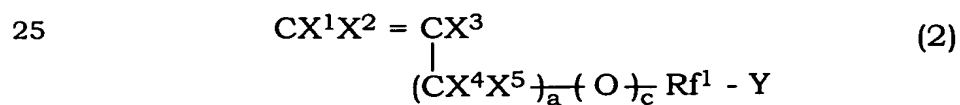
Rf in the fluorine-containing monomer of the formula (1) is preferably a fluorine-containing alkyl group having 1 to 40 carbon atoms in which 1 to 4 hydrophilic groups Y are bonded or a fluorine-containing alkyl group having 2 to 100 carbon atoms and ether bond in which 1 to 4 hydrophilic groups Y are bonded. Usually Rf having one hydrophilic group Y is preferred.

Also preferred as the Rf is a perfluoro alkyl group having 1 to 40 carbon atoms in which hydrophilic group is bonded or a perfluoro alkyl group having 2 to 100 carbon atoms and ether bond in which hydrophilic group is bonded, from the point that a refractive index of the polymer can be decreased more.

Preferred examples of the hydrophilic group Y are the same as those exemplified above.

The fluorine-containing monomer of the formula (1) is preferred because polymerizability thereof is good and homopolymerization thereof or copolymerization with other fluorine-containing ethylenic monomer is possible.

The first preferred example of the fluorine-containing ethylenic monomer of the formula (1) having the hydrophilic group Y is a monomer represented by the formula (2):



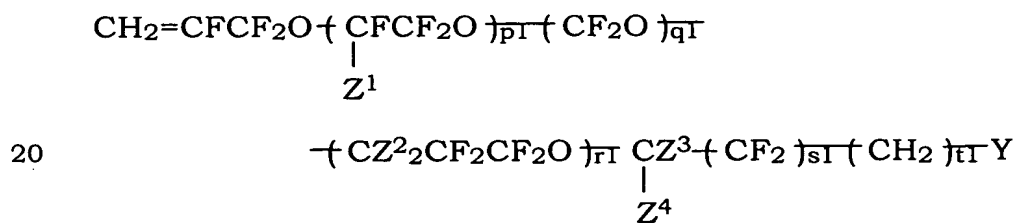
wherein  $X^1$ ,  $X^2$ ,  $X^3$ ,  $X^4$ ,  $X^5$ ,  $a$ ,  $c$  and  $Y$  are as defined in the formula (1);  $Rf^1$  is a divalent fluorine-containing alkylene group having 1 to 40 carbon atoms or a divalent fluorine-containing alkylene group having 2 to 100 carbon atoms and ether bond. The fluorine-containing ethylenic monomer of the formula (2) is preferred because polymerizability thereof is good and homopolymerization or copolymerization with other fluorine-containing ethylenic monomer is possible.

Examples of the fluorine-containing ethylenic monomer (2) having hydrophilic group  $Y$  are those represented by the formula (2-1):

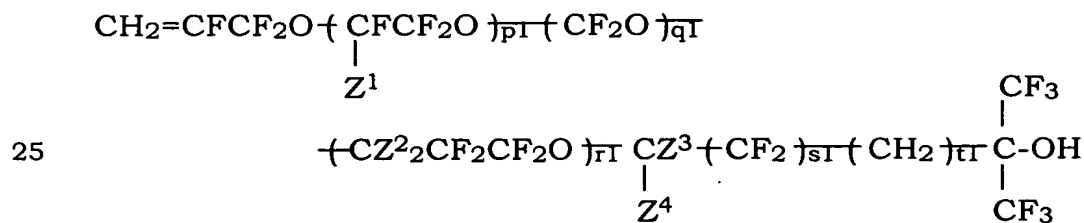


wherein  $Rf^1$  is as defined in the formula (2).

The monomers of the formula (2-1) are concretely fluorine-containing ethylenic monomers represented by:



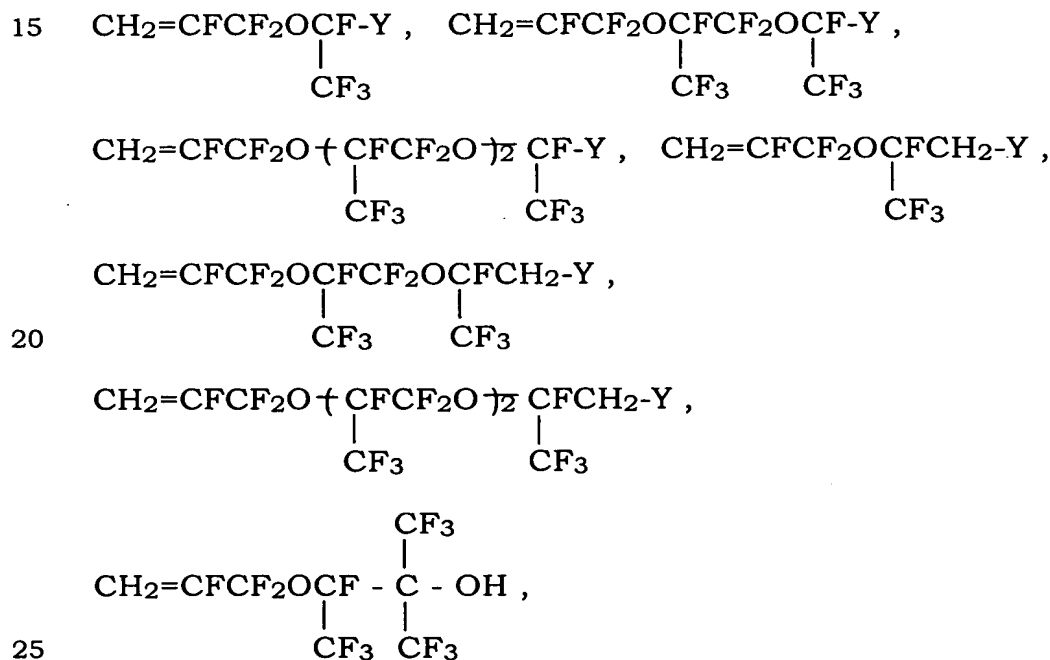
or

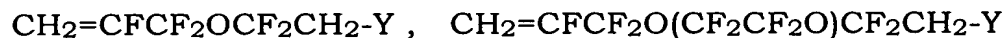
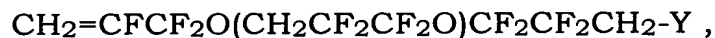
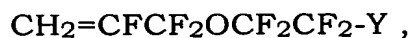
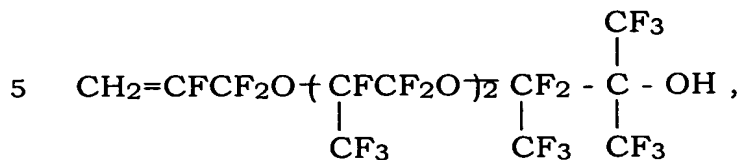
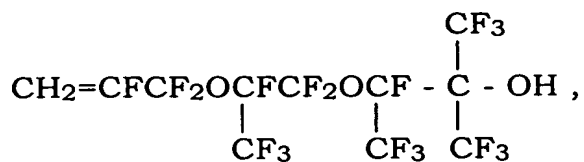


wherein  $Z^1$  is F or  $CF_3$ ;  $Z^2$  and  $Z^3$  are H or F;  $Z^4$  is H, F or  $CF_3$ ;  $p_1 + q_1 + r_1$  is 0 or an integer of 1 to 10;  $s_1$  is 0 or 1;  $t_1$  is 0 or an integer of 1 to 5; when both of  $Z^3$  and  $Z^4$  are H,  $p_1 + q_1 + r_1 + s_1$  is not 0. Those monomers are preferred because homopolymerizability thereof is excellent and more hydrophilic groups Y can be introduced to the fluorine-containing polymer, thereby enabling a low refractive index and excellent water solubility and solubility in a developing solution to be imparted to the antireflection layer (L2).

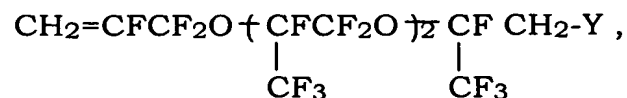
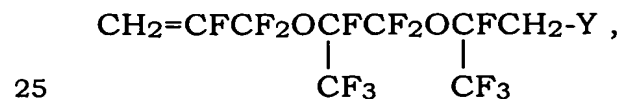
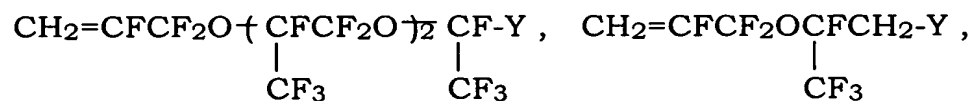
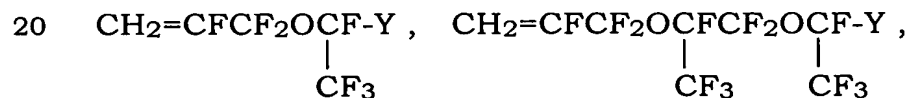
Also those monomers have high copolymerizability with fluorine-containing ethylene such as tetrafluoroethylene or vinylidene fluoride and can impart a low refractive index to the antireflection layer (L2).

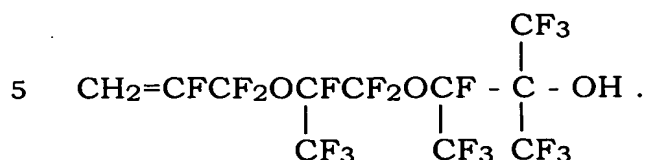
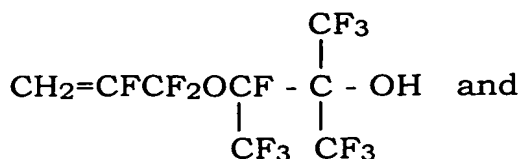
Further examples thereof are:





and the like. Among them, preferred are:



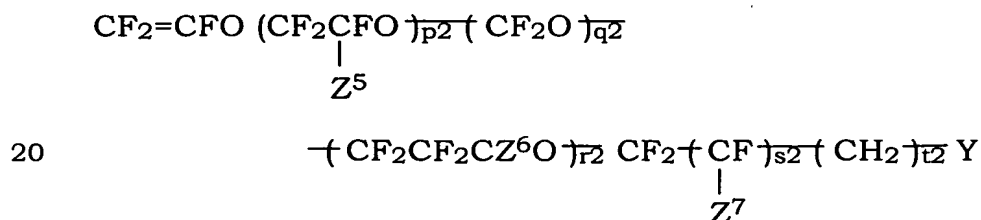


Further examples of the fluorine-containing monomer of the formula (2) having the hydrophilic group Y are fluorine-containing ethylenic monomers represented by the formula (2-2):



wherein Rf<sup>1</sup> is as defined in the formula (2).

The monomers of the formula (2-2) are concretely fluorine-containing ethylenic monomers represented by:



wherein Z<sup>5</sup> is F or CF<sub>3</sub>; Z<sup>6</sup> is H or F; Z<sup>7</sup> is H or F; p<sub>2</sub> + q<sub>2</sub> + r<sub>2</sub> is 0 or an integer of 1 to 10; s<sub>2</sub> is 0 or 1; t<sub>2</sub> is 0 or an integer of 1 to 5. Those monomers are have high copolymerizability with fluorine-containing ethylene such as tetrafluoroethylene or vinylidene fluoride and can impart a low refractive index to the antireflection layer (L2).

Further examples of the monomer of the formula (2-2) are:

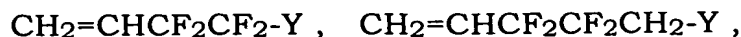
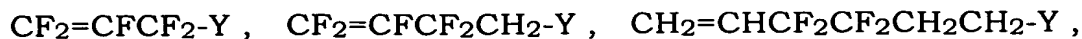
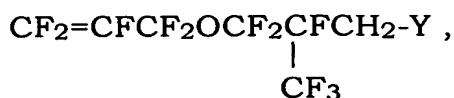
- $$\text{CF}_2=\text{CFOCF}_2\text{CF}_2\text{-Y} , \quad \text{CF}_2=\text{CFOCF}_2\underset{\text{CF}_3}{\text{CFO}_2\text{CF}_2\text{CF}_2\text{-Y}} ,$$
- 5  $\text{CF}_2=\text{CFOCF}_2\text{CF}_2\text{CF}_2\text{-Y} , \quad \text{CF}_2=\text{CFOCF}_2\text{CF}_2\text{CH}_2\text{-Y} ,$   
 $\text{CF}_2=\text{CFOCF}_2\underset{\text{CF}_3}{\text{CFO}_2\text{CF}_2\text{CF}_2\text{CH}_2\text{-Y}} ,$   
 $\text{CF}_2=\text{CFOCF}_2\text{CF}_2\text{CF}_2\text{CH}_2\text{-Y} , \quad \text{CF}_2=\text{CFOCF}_2\text{CF}_2\text{OCF}_2\text{-Y} ,$   
 $\text{CF}_2=\text{CFOCF}_2\text{CF}_2\text{OCF}_2\text{CF}_2\text{-Y} ,$   
10  $\text{CF}_2=\text{CFOCF}_2\text{CF}_2\text{CH}_2\text{OCF}_2\text{CF}_2\text{-Y} ,$   
 $\text{CF}_2=\text{CFOCF}_2\text{CF}_2\text{OCF}_2\text{CH}_2\text{-Y} ,$   
 $\text{CF}_2=\text{CFOCF}_2\text{CF}_2\text{CF}_2\text{OCF}_2\text{CF}_2\text{CH}_2\text{-Y} ,$   
 $\text{CF}_2=\text{CFOCF}_2\text{CF}_2\text{CH}_2\text{OCF}_2\text{CF}_2\text{CH}_2\text{-Y}$
- 15 and the like.

Examples of other fluorine-containing ethylenic monomer of the formula (2) having hydrophilic group Y are:

- $$\text{CF}_2=\text{CFCF}_2\text{-O-Rf}^1\text{-Y} , \quad \text{CF}_2=\text{CF-Rf}^1\text{-Y} ,$$
- 20  $\text{CH}_2=\text{CF-Rf}^1\text{-Y} \quad \text{and} \quad \text{CH}_2=\text{CH-O-Rf}^1\text{-Y},$

wherein Rf<sup>1</sup> is as defined in the formula (2), and there are concretely:

- $$\text{CF}_2=\text{CFCF}_2\text{OCF}_2\text{CF}_2\text{CF}_2\text{-Y} ,$$
- 25  $\text{CF}_2=\text{CFCF}_2\text{OCF}_2\underset{\text{CF}_3}{\text{CF-Y}} ,$   
 $\text{CF}_2=\text{CFCF}_2\text{OCF}_2\text{CF}_2\text{CF}_2\text{CH}_2\text{-Y} ,$

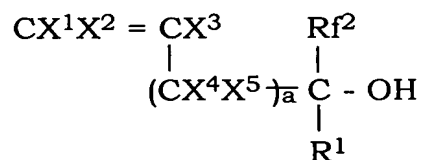


and the like.

Examples of the hydrophilic group Y of those  
10 fluorine-containing monomers are preferably those exemplified supra,  
and particularly preferred are -OH and -COOH, especially -COOH.

The second of preferred fluorine-containing ethylenic  
monomers of the formula (1) having the hydrophilic group Y are those  
represented by the formula (3):

15



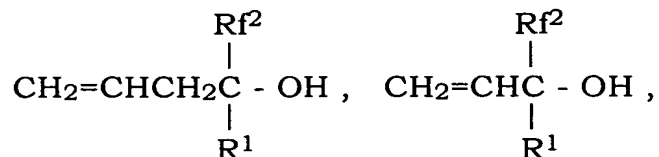
20 wherein X<sup>1</sup>, X<sup>2</sup>, X<sup>3</sup>, X<sup>4</sup>, X<sup>5</sup> and a are as defined in the formula (1); Rf<sup>2</sup>  
is a fluorine-containing alkyl group which has 1 to 10 carbon atoms  
and may have ether bond; R<sup>1</sup> is at least one selected from the group  
consisting of H, a hydrocarbon group having 1 to 10 carbon atoms and  
a fluorine-containing alkyl group which has 1 to 10 carbon atoms and  
25 may have ether bond.

The fluorine-containing polymers obtained therefrom are  
excellent particularly in transparency and low in a refractive index,

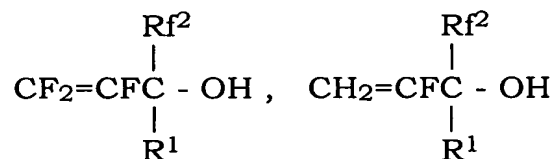
and when used for the antireflection layer (L2), are effective particularly in forming an ultrafine pattern.

Preferred examples of the fluorine-containing monomers of the formula (3) are concretely:

5

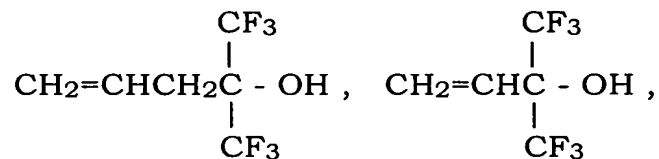


10

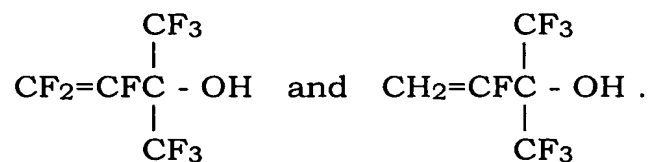


and the like, wherein Rf<sup>2</sup> and R<sup>1</sup> are as defined in the formula (3) and concretely there are:

15



20



25

The fluorine-containing polymer of the formula (M-1) to be used for the antireflection layer (L2) of the present invention may be a homopolymer of the fluorine-containing monomer of the formula (1) having the hydrophilic group or a copolymer thereof with other monomer.



In the case of a homopolymerizable monomer among the monomers of the formula (1), the homopolymer is more preferred since a dissolution rate of the antireflection layer (L2) in a developing solution can be increased.

5 In the case of a copolymer, the structural unit (N1) as a copolymerizable component can be selected optionally, but is preferably so selected as to set a refractive index low within a range of maintaining solubility in a developing solution. Concretely the structural unit (N1) is selected from structural units derived from  
10 fluorine-containing ethylenic monomers.

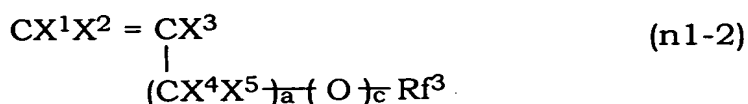
Particularly preferred are those selected from the following structural units (N1-1) and (N1-2).

(N1-1) Structural unit derived from a fluorine-containing ethylenic monomer having 2 or 3 carbon atoms and at least one fluorine atom:

15 This structural unit N1-1 is preferred because a refractive index can be effectively decreased and transparency can be improved without lowering solubility in a developing solution, and also because a strength of the antireflection layer can be improved.

Concretely there are  $\text{CF}_2=\text{CF}_2$ ,  $\text{CF}_2=\text{CFCl}$ ,  $\text{CH}_2=\text{CF}_2$ ,  
20  $\text{CFH}=\text{CH}_2$ ,  $\text{CFH}=\text{CF}_2$ ,  $\text{CF}_2=\text{CFCF}_3$ ,  $\text{CH}_2=\text{CFCF}_3$ ,  $\text{CH}_2=\text{CHCF}_3$  and the like. Among them, preferred are tetrafluoroethylene ( $\text{CF}_2=\text{CF}_2$ ), chlorotrifluoroethylene ( $\text{CF}_2=\text{CFCl}$ ) and vinylidene fluoride ( $\text{CH}_2=\text{CF}_2$ ) from the viewpoint of good copolymerizability and high effects of imparting transparency and a low refractive index.

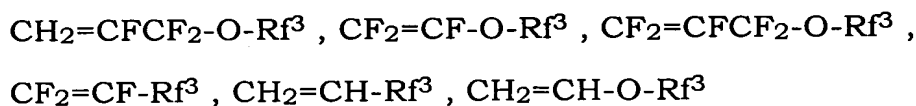
25 (N1-2) Structural unit derived from a monomer represented by the formula (n1-2):



wherein  $\text{X}^1$ ,  $\text{X}^2$ ,  $\text{X}^3$ ,  $\text{X}^4$ ,  $\text{X}^5$ ,  $a$  and  $c$  are as defined in the formula (1);  
 5  $\text{Rf}^3$  is a fluorine-containing alkyl group having 1 to 40 carbon atoms or  
 a fluorine-containing alkyl group having 2 to 100 carbon atoms and  
 ether bond.

This structural unit is preferred since a refractive index can  
 be effectively decreased and transparency can be improved effectively.

10 Preferred are:



15 and the like, wherein  $\text{Rf}^3$  is as defined in the formula (n1-2).

The proportion of each structural unit in the  
 fluorine-containing polymer of the formula (M-1) is optionally selected  
 depending on the above-mentioned preferable fluorine content and  
 hydrophilic group content. The structural units M1 and N1 are  
 20 contained in amounts of preferably from 30 to 100 % by mole and from  
 0 to 70 % by mole, further preferably from 40 to 100 % by mole and  
 from 0 to 60 % by mole, more preferably from 50 to 100 % by mole and  
 0 to 50 % by mole, especially preferably from 60 to 100 % by mole and  
 from 0 to 40 % by mole, respectively.

25 The number average molecular weight of the  
 fluorine-containing polymer of the formula (M-1) is from 1,000 to  
 1,000,000, preferably from 2,000 to 200,000, more preferably from

3,000 to 100,000, particularly preferably from 5,000 to 50,000.

If the molecular weight is too low, there is a case where there arise problems that a strength of the antireflection layer (L2) becomes too low and the fluorine-containing polymer itself penetrates  
5 into the lower photoresist layer (L1). Also there is a case where film forming property of the antireflection layer is lowered and as a result, formation of a uniform thin film becomes difficult.

The second of the preferred fluorine-containing polymer (A) to be used for the antireflection layer (L2) of the present invention is  
10 represented by the formula (M-2):



wherein the structural unit M2 is a structural unit derived from a  
15 fluorine-containing monomer which has -COOH group as the hydrophilic group Y and is represented by the formula (4):



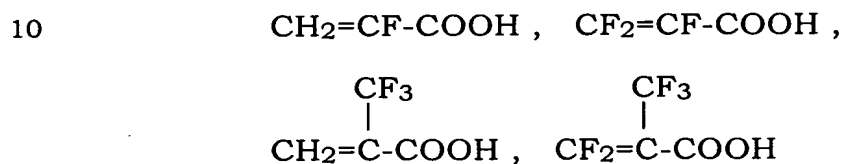
20

wherein  $X^6$  and  $X^7$  are the same or different and each is H or F;  $X^8$  is H, F, Cl,  $CH_3$  or  $CF_3$ ; at least one of  $X^6$ ,  $X^7$  and  $X^8$  contains fluorine atom, the structural unit N2 is a structural unit derived from a monomer copolymerizable with the fluorine-containing monomer of the formula  
25 (4), and

the structural units M2 and N2 are contained in amounts of from 10 to 100 % by mole and from 0 to 90 % by mole, respectively.

This fluorine-containing polymer contains, as a component for imparting water solubility and solubility in a developing solution, a structural unit derived from a fluorine-containing acrylic acid which is a fluorine-containing monomer having -COOH group as the hydrophilic group Y. This polymer is preferred particularly from the viewpoint of excellent water solubility and solubility in a developing solution.

Examples of the fluorine-containing monomer of the formula (4) are:



and the like, and particularly preferred are:



from the viewpoint of good polymerizability.

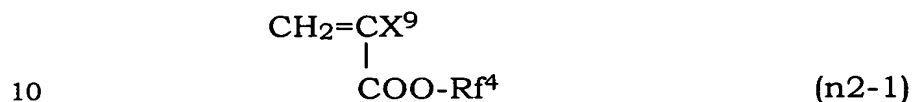
20                    The fluorine-containing polymer (M-2) to be used for the antireflection layer (L2) of the present invention may be a homopolymer of the fluorine-containing monomer of the formula (4), but it is usually preferable that the polymer contains the optional structural unit N2 by copolymerization.

25                    The structural unit N2 of copolymerizable component can be selected optionally, but is preferably so selected as to set a refractive index low within a range of maintaining solubility in a developing

solution. The structural unit N2 is concretely selected from structural units of the following fluorine-containing ethylenic monomers.

(N2-1) Structural unit derived from a fluorine-containing acrylate monomer:

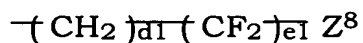
5                      Concretely preferred are structural units derived from fluorine-containing acrylate monomers represented by the formula (n2-1):



wherein  $\text{X}^9$  is H, F or  $\text{CH}_3$ ;  $\text{Rf}^4$  is a fluorine-containing alkyl group having 1 to 40 carbon atoms or a fluorine-containing alkyl group having 2 to 100 carbon atoms and ether bond. Those monomers are  
15 preferred since copolymerizability with the fluorine-containing monomer of the formula (4) is high and a low refractive index can be imparted to the fluorine-containing polymer.

In the fluorine-containing acrylate of the formula (n2-1), examples of  $\text{Rf}^4$  group are:

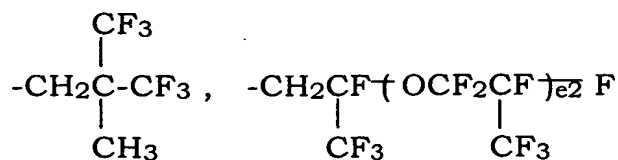
20



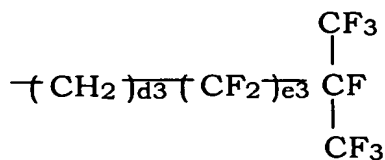
( $\text{Z}^8$  is H, F or Cl;  $d1$  is an integer of 1 to 4;  $e1$  is an integer of 1 to 10),



25



( $e2$  is an integer of 1 to 5),



(d3 is an integer of 1 to 4; e3 is an integer of 1 to 10)

5

and the like.

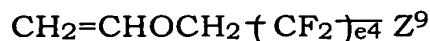
(N2-2) Structural unit derived from a fluorine-containing vinyl ether monomer:

Concretely preferred are structural units derived from  
10 fluorine-containing vinyl ethers represented by the formula (n2-2):

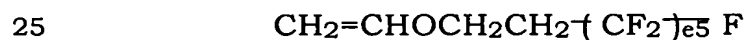


wherein Rf<sup>5</sup> is a fluorine-containing alkyl group having 1 to 40 carbon  
15 atoms or a fluorine-containing alkyl group having 2 to 100 carbon  
atoms and ether bond. Those monomers are preferred since  
copolymerizability with the fluorine-containing monomer of the formula  
(4) is high and a low refractive index can be imparted to the  
fluorine-containing polymer.

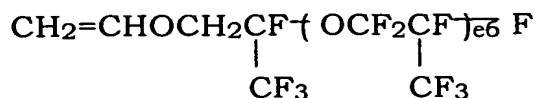
20 Preferred examples of the monomer of the formula (n2-2)  
are:



(Z<sup>9</sup> is H or F; e4 is an integer of 1 to 10),



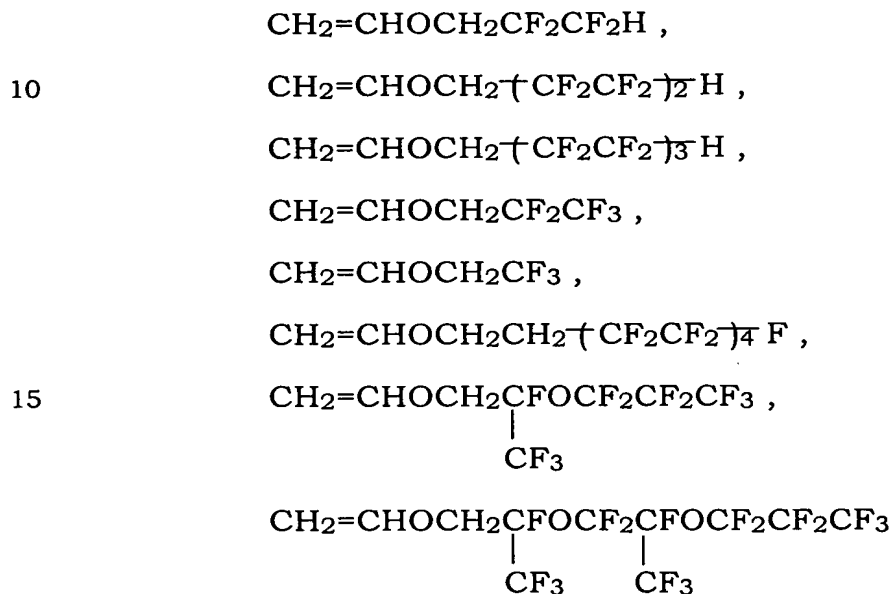
(e5 is an integer of 1 to 10),



(e6 is an integer of 1 to 10)

5 and the like.

More concretely there are structural units derived from the following monomers:

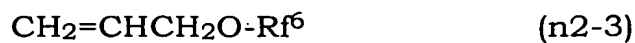


20 and the like.

Also there are the following structural units (N2-3) and (N2-4).

(N2-3) Structural unit derived from a fluorine-containing allyl ether represented by the formula (n2-3):

25



wherein  $Rf^6$  is a fluorine-containing alkyl group having 1 to 40 carbon atoms or a fluorine-containing alkyl group having 2 to 100 carbon atoms and ether bond.

(N2-4) Structural unit derived from a fluorine-containing vinyl monomer represented by the formula (n2-4):

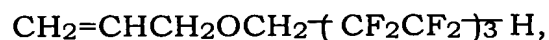


wherein  $Rf^7$  is a fluorine-containing alkyl group having 1 to 40 carbon atoms or a fluorine-containing alkyl group having 2 to 100 carbon atoms and ether bond.

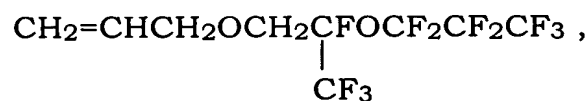
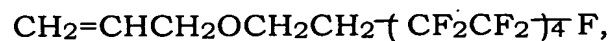
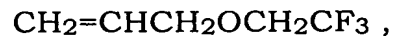
Those structural units are preferred since a low refractive index can be given to the fluorine-containing polymer.

Examples of the monomers (n2-3) and (n2-4) are:

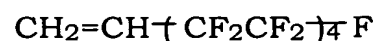
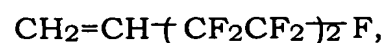
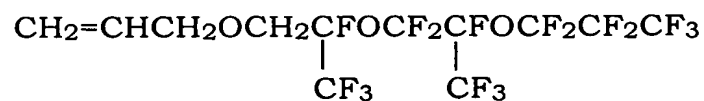
15



20



25





and the like.

The proportion of each structural unit in the fluorine-containing polymer of the formula (M-2) is optionally selected depending on the above-mentioned preferred fluorine content and hydrophilic group content. The structural units M2 and N2 are contained in amounts of preferably from 10 to 100 % by mole and from 0 to 90 % by mole, further preferably from 20 to 80 % by mole and from 20 to 80 % by mole, more preferably from 30 to 70 % by mole and from 30 to 70 % by mole, especially preferably from 40 to 60 % by mole and from 40 to 60 % by mole, respectively.

If the proportion of the structural unit (M2) is too low, water solubility and solubility in a developing solution become insufficient, and if the proportion of the structural unit (M2) is too high, a refractive index becomes too high. Therefore the both cases are not preferred.

The number average molecular weight of the fluorine-containing polymer of the formula (M-2) is from 1,000 to 1,000,000, preferably from 2,000 to 200,000, more preferably from 3,000 to 100,000, particularly preferably from 5,000 to 50,000.

If the molecular weight is too low, there is a case where there arise problems that a strength of the antireflection layer (L2) becomes too low and the fluorine-containing polymer itself penetrates into the lower photoresist layer (L1). Also there is a case where film forming property of the antireflection layer is lowered and as a result, formation of a uniform thin film becomes difficult.

Preferred examples of the fluorine-containing polymer (A) to be used for the antireflection layer (L2) of the present invention are fluorine-containing polymers represented by the following formulae

(M-1-1), (M-1-2) and (M-2-1).

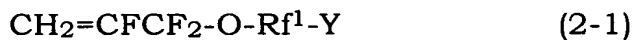
Fluorine-containing polymer which has a number average molecular weight of from 1,000 to 200,000 and is represented by the formula (M-1-1):

5



wherein the structural unit M1-1 is a structural unit derived from a monomer represented by the formula (2-1):

10



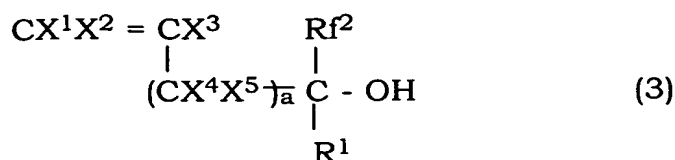
in which  $Rf^1$  is as defined in the formula (2). Namely, the fluorine-containing polymer (A) is a fluorine-containing allyl ether homopolymer containing one or more monomers selected from the monomers of the formula (2-1). This polymer is preferred since both of a high fluorine content and a high hydrophilic group content can be obtained, thereby giving a low refractive index and excellent solubility in a developing solution.

20 Fluorine-containing polymer which has a number average molecular weight of from 1,000 to 200,000 and is represented by the formula (M-1-2):

25



wherein the structural unit M1-2 is a structural unit derived from a monomer represented by the formula (3):



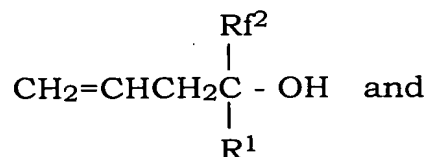
5 wherein  $\text{X}^1$ ,  $\text{X}^2$ ,  $\text{X}^3$ ,  $\text{X}^4$ ,  $\text{X}^5$ ,  $\text{Rf}^2$ ,  $\text{R}^1$  and  $a$  are as defined in the formula (3) mentioned supra,

the structural unit N1-1 is a structural unit derived from a fluorine-containing ethylenic monomer having 2 or 3 carbon atoms and at least one fluorine atom, and

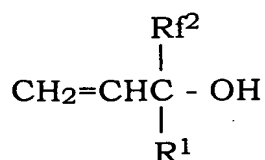
10 the structural units M1-2 and N1-1 are contained in amounts of from 30 to 70 % by mole and from 30 to 70 % by mole, respectively.

Preferred monomers for the structural unit M1-2 are those exemplified supra in the monomers of the formula (3). Particularly preferred are structural units derived from monomers selected from:

15



20



wherein  $\text{Rf}^2$  and  $\text{R}^1$  are as defined in the formula (3).

It is preferable that the structural unit N1-1 is a structural unit derived from a monomer selected from tetrafluoroethylene and chlorotrifluoroethylene.

Those monomers are preferred since transparency thereof is

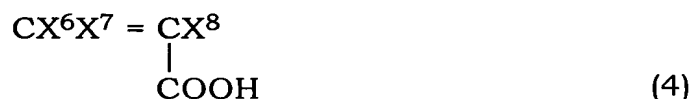
high particularly in the case of light in a vacuum ultraviolet region and a refractive index can be set low.

Fluorine-containing polymer which has a number average molecular weight of from 1,000 to 200,000 and is represented by the formula

5 (M-2-1):



wherein the structural unit M2 is a structural unit derived from a  
10 monomer represented by the formula (4):



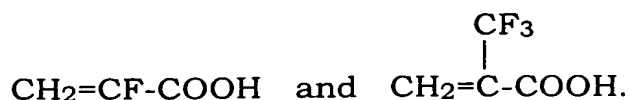
15 wherein  $X^6$ ,  $X^7$  and  $X^8$  are as defined in the formula (4) explained supra,

the structural unit N2-2 is a structural unit derived from a monomer represented by the formula (n2-2):

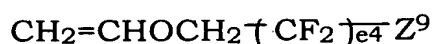


in which  $Rf^5$  is as defined in the formula (n2-2) explained supra, and the structural units M2 and N2-2 are contained in amounts of from 30 to 70 % by mole and from 30 to 70 % by mole, respectively.

25 Preferred monomers for the structural unit M2 are those exemplified supra in the monomers of the formula (4). Particularly preferred are structural units derived from monomers selected from:



Preferred monomers for the structural unit N2-2 are those  
5 exemplified supra in the monomers of the formula (n2-2). Particularly  
preferred are structural units derived from monomers represented by:



10 wherein  $\text{Z}^9$  is H or F;  $e4$  is an integer of 1 to 10.

Those polymers are preferred particularly because of  
excellent water solubility and solubility in a developing solution.

In the method of forming the laminated photoresist of the  
present invention, the antireflection layer (L2) is formed on the  
15 previously formed photoresist layer (L1) by applying the coating  
composition containing the above-mentioned fluorine-containing  
polymer (A).

The coating composition for forming the antireflection layer  
(L2) contains:

20 (A) the fluorine-containing polymer having the hydrophilic group Y and  
(B) at least one solvent selected from the group consisting of water and  
alcohols.

It is preferable that the solvent (B) is selected from solvents  
which do not re-dissolve the previously formed lower photoresist layer  
25 (L1) when the coating composition is applied. From this point of view,  
the solvent (B) is preferably water and/or alcohols.

The fluorine-containing polymer (A) of the present invention

has good solubility in those water and alcohols.

Among the solvents (B), water is not limited particularly. Preferred are distilled water, ion exchange water, water subjected to filtration and water subjected to adsorption treatment to remove  
5 organic impurities and metal ion.

Alcohols are optionally selected from those which do not re-dissolve the photoresist layer (L1), depending on kind of the photoresist layer (L1). Generally lower alcohols are preferred, and concretely methanol, ethanol, isopropanol, n-propanol and the like are  
10 preferred.

In addition to the solvent (B), a water soluble organic solvent may be used together for the purpose of improving coatability, etc. within a range not re-dissolving the photoresist layer (L1).

A water soluble organic solvent is not limited particularly as  
15 far as it dissolves in water in an amount of not less than 1 % by mass. Preferred examples thereof are, for instance, ketones such as acetone and methyl ethyl ketone; esters of acetic acids such as methyl acetate and ethyl acetate; polar solvents such as dimethylformamide, dimethyl sulfoxide, methyl cellosolve, cellosolve acetate, butyl cellosolve, butyl  
20 carbitol and carbitol acetate; and the like.

An adding amount of the water soluble organic solvent to be added in addition to water or alcohol is from 0.1 to 50 % by mass, preferably from 0.5 to 30 % by mass, more preferably from 1 to 20 % by mass, particularly preferably from 1 to 10 % by mass based on the  
25 total amount of the solvent (B).

To the coating composition forming the antireflection layer (L2) of the present invention may be added, as case demands, at least

one selected from basic substances, for example, ammonia and organic amines. In this case, there is a case where an acidic OH group having a pKa value of not more than 11 may be a hydrophilic moiety in the form of derivative, for example, ammonium salt, amine salt or the like  
5 in the coating composition.

Especially when the hydrophilic group Y in the fluorine-containing polymer (A) is -COOH or -SO<sub>3</sub>H, the addition of the basic substance is effective for enhancing water solubility and solubility in a developing solution and also for maintaining  
10 repeatability of a dissolution rate in a developing solution. Also it is effective for adjusting the pH value of the coating composition to be within an optimum range.

With respect to the organic amines, preferred are water soluble organic amine compounds. Preferred examples thereof are, for  
15 instance, primary amines such as methylamine, ethylamine, propylamine, butylamine and cyclohexylamine; secondary amines such as dimethylamine, diethylamine, dipropylamine and dibutylamine; tertiary amines such as trimethylamine, triethylamine, tripropylamine, tributylamine, pyridine, pyrrole, piperidine, oxazole and morpholine;  
20 hydroxylamines such as monoethanolamine, propanolamine, diethanolamine, triethanolamine and tris(hydroxymethyl)aminomethane; quaternary ammonium compounds such as tetramethylammonium hydroxide, tetraethylammonium hydroxide, tetrapropylammonium hydroxide and tetrabutylammonium  
25 hydroxide; primary, secondary and tertiary polyamines such as ethylenediamine, diethylenediamine, tetraethylenediamine, diethylenetriamine, tetraethylenetriamine, imidazole, imidazolidine,

pyrazine and s-triazine ; and the like.

Among them, from the point of maintaining a low refractive index and increasing a dissolution rate in a developing solution, preferred are hydroxylamines such as monoethanolamine, 5 propanolamine, diethanolamine, triethanolamine and tris(hydroxymethyl)aminomethane, and particularly preferred is monoethanolamine.

In the coating composition, ammonia or organic amine can be added usually in an amount of from 0.01 to 10 mole, preferably 10 from 0.1 to 5 mole, more preferably from 0.5 to 1 mole based on 1 mole of hydrophilic group of the fluorine-containing polymer (A) to be used.

To the coating composition forming the antireflection layer (L2) of the present invention may be added, as case demands, a known surfactant.

15 The addition of a surfactant is effective for improving wettability of the coating composition to the surface of the lower photoresist layer (L1) and for forming a uniform thin film, and further is preferred for decreasing a surface tension of the obtained antireflection layer (L2) after the coating, thereby resulting in 20 stabilization of solubility in a developing solution. Further the addition of surfactant is preferred for preventing striation.

Examples of the surfactant to be added are nonionic surfactants, anionic surfactants and ampholytic surfactants, and anionic surfactants are used preferably.

25 Examples of nonionic surfactants are polyoxyethylene alkyl ethers, for instance, polyoxyethylene lauryl ether, polyoxyethylene stearyl ether, polyoxyethylene oleyl ether, polyoxyethylene cetyl ether,

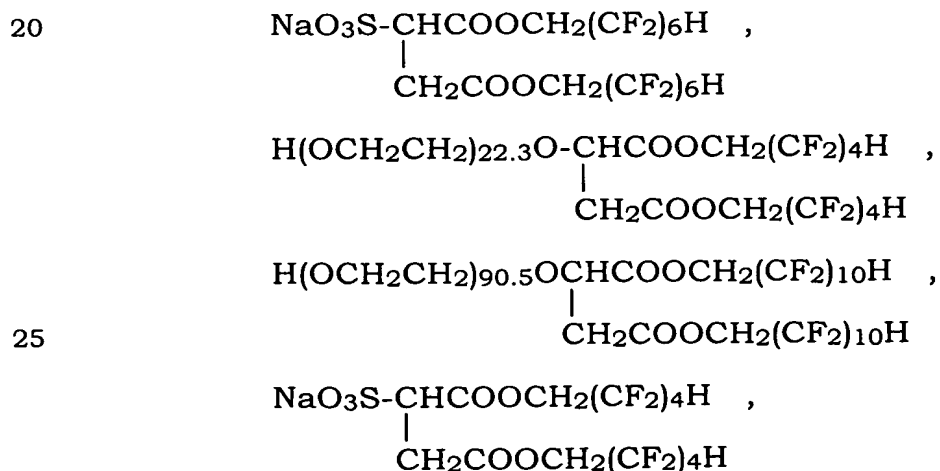


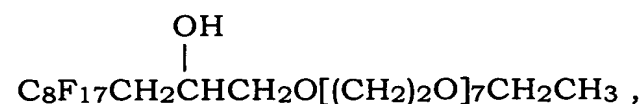
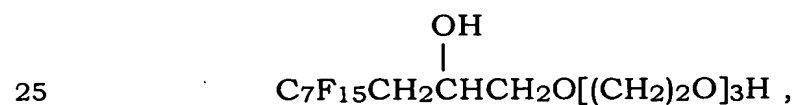
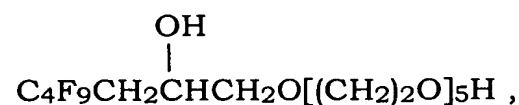
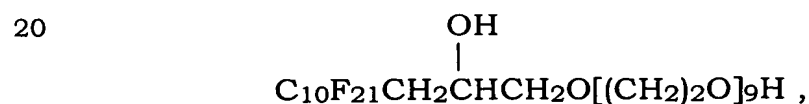
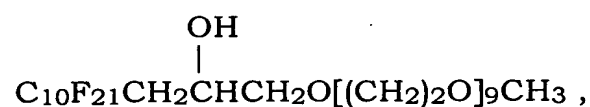
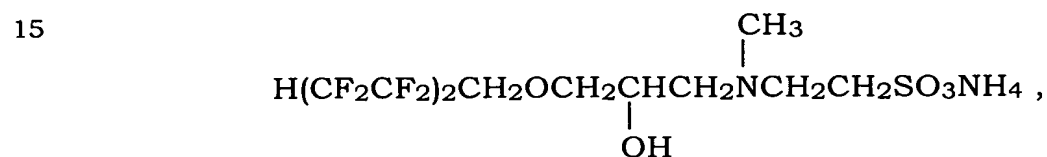
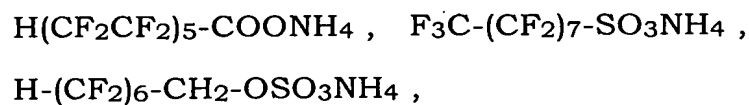
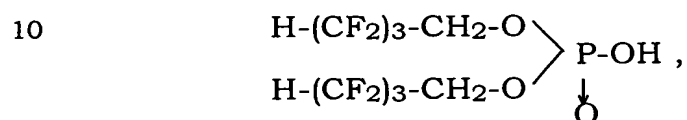
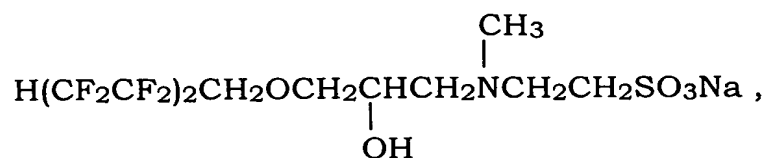
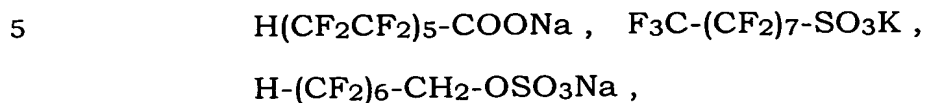
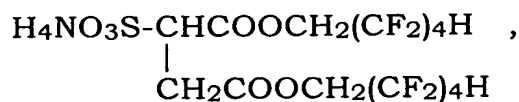
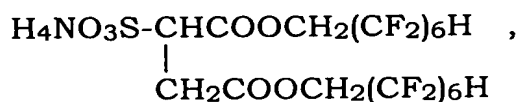
polyoxyethylene octyl phenyl ether, polyoxyethylene nonyl phenyl ether, polyethylene glycol dilaurate and polyethylene glycol distearate; polyoxyethylene fatty acid diester, polyoxy fatty acid monoester, polyoxyethylene/polyoxypropylene block polymer, acetylene glycol  
5 derivative and the like.

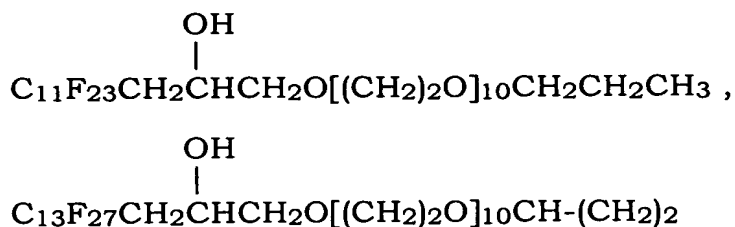
Examples of the anionic surfactants are alkyl diphenylether disulfonic acid and its ammonium salt or organic amine salt; alkyl diphenylether sulfonic acid and its ammonium salt or organic amine salt; alkylbenzene sulfonic acid and its ammonium salt or organic  
10 amine salt; polyoxyethylene alkyl ether sulfuric acid and its ammonium salt or organic amine salt; alkyl sulfuric acid and its ammonium salt or organic amine salt; and the like.

Examples of ampholytic surfactants are 2-alkyl-N-carboxymethyl-N-hydroxyethyl imidazolinium betaine, lauric  
15 acid amidopropylhydroxysulfone betaine and the like.

Also fluorine-containing surfactants are preferred because a low refractive index of the antireflection layer (L2) can be maintained. Examples thereof are:







5

and the like

With respect to the fluorine-containing surfactants, not only the above-mentioned low molecular weight compounds but also the following high molecular weight compounds are preferred because a  
10 low refractive index of the antireflection layer (L2) can be maintained.

There are concretely copolymers having a number average molecular weight of 1,000 to 500,000 and containing component units derived from (a) acrylic ester or methacrylic acid ester having fluoroalkyl group (monomer (a)), (b) polyalkylene glycol acrylate or  
15 polyalkylene glycol methacrylate (monomer (b)), (c) 3-chloro-2-hydroxypropyl (meth)acrylate (monomer (c)) and (d) glycerol mono(meth)acrylate (monomer (d)), and fluorine-containing polymer surfactants containing such a copolymer.

The monomers providing each component unit are  
20 explained below.

Examples of the monomer (a) are, for instance, one or two or more compounds represented by the formula:



25

wherein  $\text{Rf}^{20}$  is a linear or branched perfluoroalkyl group having 3 to 20 carbon atoms;  $\text{R}^{11}$  is hydrogen atom or methyl;  $\text{R}^{10}$  is a linear or

branched alkylene group having 1 to 10 carbon atoms,  $-\text{SO}_2\text{N}(\text{R}^{12})\text{R}^{13}-$  group ( $\text{R}^{12}$  is an alkyl group having 1 to 10 carbon atoms;  $\text{R}^{13}$  is a linear or branched alkylene group having 1 to 10 carbon atoms) or  $-\text{CH}_2\text{CH}(\text{OR}^{14})\text{CH}_2-$  group ( $\text{R}^{14}$  is hydrogen atom or an acyl group having 1 to 10 carbon atoms).

Examples of the monomer (a) are as follows. These monomers may be used alone or in a mixture of two or more thereof.

(a-1)  $\text{CF}_3(\text{CF}_2)_n(\text{CH}_2)_m\text{OCOCR}^{11}=\text{CH}_2$  ( $\text{R}^{11}$  is hydrogen atom or methyl;  $n$  is an integer of 2 to 19,  $m$  is an integer of 1 to 10)

Examples thereof are:

$\text{CF}_3(\text{CF}_2)_7(\text{CH}_2)_{10}\text{OCOCH}=\text{CH}_2$  ,  
 $\text{CF}_3(\text{CF}_2)_7(\text{CH}_2)_2\text{OCOCH}=\text{CH}_2$  ,  
 $\text{CF}_3(\text{CF}_2)_6\text{CH}_2\text{OCOC}(\text{CH}_3)=\text{CH}_2$  ,  
 $\text{CF}_3(\text{CF}_2)_7(\text{CH}_2)_2\text{OCOC}(\text{CH}_3)=\text{CH}_2$  ,  
 $\text{CF}_3(\text{CF}_2)_9(\text{CH}_2)_2\text{OCOC}(\text{CH}_3)=\text{CH}_2$  ,  
 $\text{CF}_3(\text{CF}_2)_{11}(\text{CH}_2)_2\text{OCOC}(\text{CH}_3)=\text{CH}_2$  ,

and the like.

(a-2)  $(\text{CF}_3)_2\text{CF}(\text{CF}_2)_n(\text{CH}_2)_m\text{OCOCR}^{11}=\text{CH}_2$  ( $\text{R}^{11}$  is hydrogen atom or methyl;  $n$  is 0 or an integer of 1 to 17,  $m$  is an integer of 1 to 10)

Examples thereof are:

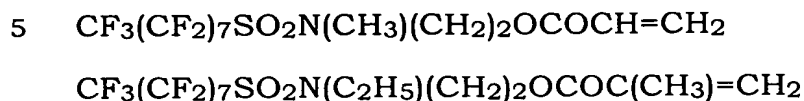
$(\text{CF}_3)_2\text{CF}(\text{CF}_2)_8(\text{CH}_2)_2\text{OCOCH}=\text{CH}_2$

and the like.

(a-3)  $\text{CF}_3(\text{CF}_2)_n\text{SO}_2\text{N}(\text{R}^{12})(\text{CH}_2)_m\text{OCOCR}^{11}=\text{CH}_2$  ( $\text{R}^{11}$  is hydrogen atom

or methyl;  $R^{12}$  is an alkyl group having 1 to 10 carbon atoms; n is an integer of 2 to 19, m is an integer of 1 to 10)

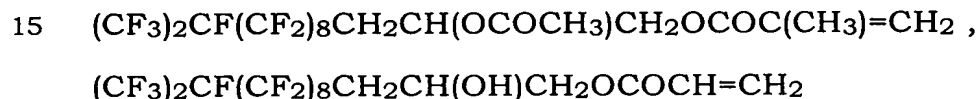
Examples thereof are:



and the like.

(a-4)  $(CF_3)_2CF(CF_2)_nCH_2CH(OR^{14})(CH_2)_mOCOCR^{11}=CH_2$  ( $R^{11}$  is  
 10 hydrogen atom or methyl;  $R^{14}$  is hydrogen atom or an acyl group  
 having 1 to 10 carbon atoms; n is 0 or an integer of 1 to 17, m is an  
 integer of 1 to 10)

Examples thereof are:



and the like.

Preferred examples of the monomer (b) are, for instance, one  
 20 or two or more compounds represented by the formula:



wherein  $R^{15}$  and  $R^{17}$  are hydrogen atom or methyl;  $R^{16}$  is an alkylene  
 25 group having 2 to 6 carbon atoms, n is an integer of 3 to 50.

Usually  $-CH_2CH_2-$  is suitable as  $R^{16}$ .  $R^{16}$  may be  
 $-CH(CH_3)CH_2-$ ,  $-CH(C_2H_5)CH_2-$  or the like. Namely, in the present

invention, polyethylene glycol acrylate or methacrylate in which  $R^{16}$  is  $-\text{CH}_2\text{CH}_2-$  can be used particularly preferably. Also,  $n$  is selected from integers of 3 to 50, and usually when  $n$  is selected from integers of 9 to 25, especially good result can be obtained. It is a matter of course  
 5 that the monomer (b) may be in the form of a mixture of two or more monomers having different kind of  $R^{16}$  and different number of  $n$ .

Examples of the monomer (b) are as follows. These monomers may be used alone or in a mixture of two or more thereof.

(b-1)  $\text{CH}_2=\text{CR}^{15}\text{COO}(\text{CH}_2\text{CH}_2\text{O})_n\text{R}^{17}$  ( $R^{15}$  and  $R^{17}$  are hydrogen atom or  
 10 methyl;  $n$  is an integer of 3 to 50)

Examples thereof are:

$\text{CH}_2=\text{C}(\text{CH}_3)\text{COO}(\text{CH}_2\text{CH}_2\text{O})_3\text{H}$  ,  
 $\text{CH}_2=\text{C}(\text{CH}_3)\text{COO}(\text{CH}_2\text{CH}_2\text{O})_6\text{H}$  ,  
 15  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COO}(\text{CH}_2\text{CH}_2\text{O})_9\text{H}$  ,  
 $\text{CH}_2=\text{C}(\text{CH}_3)\text{COO}(\text{CH}_2\text{CH}_2\text{O})_{40}\text{H}$  ,  
 $\text{CH}_2=\text{C}(\text{CH}_3)\text{COO}(\text{CH}_2\text{CH}_2\text{O})_9\text{CH}_3$  ,  
 $\text{CH}_2=\text{C}(\text{CH}_3)\text{COO}(\text{CH}_2\text{CH}_2\text{O})_{23}\text{CH}_3$

20 and the like.

(b-2)  $\text{CH}_2=\text{CR}^{15}\text{COO}(\text{CH}_2\text{CH}(\text{CH}_3)\text{O})_n\text{R}^{17}$  ( $R^{15}$  and  $R^{17}$  are hydrogen atom or methyl;  $n$  is an integer of 3 to 50)

Examples thereof are:

25  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COO}(\text{CH}_2\text{CH}(\text{CH}_3)\text{O})_{12}\text{H}$  ,  
 $\text{CH}_2=\text{CHCOO}(\text{CH}_2\text{CH}(\text{CH}_3)\text{O})_{11}\text{CH}_3$

and the like.

(b-3)  $\text{CH}_2=\text{CR}^{15}\text{COO}(\text{CH}_2\text{CH}_2\text{O})_n(\text{CH}_2\text{CH}(\text{CH}_3)\text{O})_m\text{R}^{17}$  ( $\text{R}^{15}$  and  $\text{R}^{17}$  are hydrogen atom or methyl;  $n + m$  is an integer of 3 to 50)

Examples thereof are:

5



and the like.

3-Chloro-2-hydroxypropyl (meth)acrylate of the monomer (c)  
10 is 3-chloro-2-hydroxypropyl acrylate and/or 3-chloro-2-hydroxypropyl methacrylate represented by:



15 wherein  $\text{R}^{18}$  is hydrogen atom or methyl.

Glycerol mono(meth)acrylate of the monomer (d) is glycerol monoacrylate and/or glycerol monomethacrylate represented by:



20

wherein  $\text{R}^{19}$  is hydrogen atom or methyl.

In the copolymer to be used in the present invention as a fluorine-containing polymer surfactant, a copolymerization ratio of the (meth)acrylic acid ester (monomer (a)) having fluoroalkyl group is at  
25 least 5 % by mass, preferably from 6 to 70 % by mass.

A copolymerization ratio of the polyalkylene glycol (meth)acrylate (monomer (b)) is at least 10 % by mass, preferably from

14 to 60 % by mass. If the ratio is less than 10 % by mass, dispersibility in water tends to be lowered.

A copolymerization ratio of the 3-chloro-2-hydroxypropyl (meth)acrylate (monomer (c)) is at least 0.5 % by mass, preferably from 0.5 to 30 % by mass. A copolymerization ratio of the glycerol mono(meth)acrylate (monomer (d)) is at least 0.5 % by mass, preferably from 0.5 to 30 % by mass.

It is preferable that a total copolymerization ratio of 3-chloro-2-hydroxypropyl (meth)acrylate (monomer (c)) and glycerol mono(meth)acrylate (monomer (d)) is at least 1 % by mass, preferably from 1.2 to 30 % by mass. Also it is preferable that a ratio of 3-chloro-2-hydroxypropyl (meth)acrylate (monomer (c)) to the sum of monomer (c) and monomer (d) is from 10 to 90 % by mass, particularly from 20 to 80 % by mass.

A number average molecular weight of the fluorine-containing polymer surfactant is from 1,000 to 500,000, preferably from 5,000 to 200,000. If it is less than 1,000, durability tends to be lowered, and if it exceeds 500,000, a viscosity of the surfactant solution becomes high, and there is a case where workability is lowered. The fluorine-containing polymer surfactant may be a random copolymer or a block copolymer.

With respect to those copolymers to be used as the fluorine-containing polymer surfactant, besides the monomers (a), (b), (c) and (d) can be copolymerized a copolymerizable monomer having no fluoroalkyl group such as ethylene, vinyl chloride, halogenated vinylidene, styrene, (meth)acrylic acid, alkyl ester of (meth)acrylic acid, benzyl methacrylate, vinyl alkyl ketone, vinyl alkyl ether, isoprene,



chloroprene, maleic anhydride or butadiene. When those other monomers are copolymerized, dispersibility, uniform coatability, water- and oil-repellency and durability can be enhanced and a low refractive index can be obtained. Also other various properties such as  
5 solubility and water resistance can be optionally improved. A copolymerization ratio of the comonomer having no fluoroalkyl group is from 0 to 40 % by mass, preferably from 0 to 20 % by mass.

The copolymer suitable as the fluorine-containing polymer surfactant of the present invention contains, for example, the following  
10 copolymerizable components, but the composition of the copolymer is not limited to them.

(Composition I)

Copolymer containing:

19 to 22 parts by mass of monomer (a) represented by  
15  $\text{CF}_3\text{CF}_2(\text{CF}_2\text{CF}_2)_n\text{CH}_2\text{CH}_2\text{OCOC}(\text{CH}_3)=\text{CH}_2$  (a mixture of compounds of  $n=3$ ,  $n=4$  and  $n=5$  in a weight ratio of 5:3:1),

8 to 13 parts by mass of monomer (b) represented by  
 $\text{CH}_2=\text{C}(\text{CH}_3)\text{COO}(\text{CH}_2\text{CH}_2\text{O})_9\text{CH}_3$ ,

4 to 7 parts by mass of monomer (b) represented by  
20  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COO}(\text{CH}_2\text{CH}(\text{CH}_3)\text{O})_{12}\text{H}$ ,

3 to 5 parts by mass of monomer (c) represented by  
 $\text{CH}_2=\text{C}(\text{CH}_3)\text{COOCH}_2\text{CH}(\text{OH})\text{CH}_2\text{Cl}$  and

1 to 2 parts by mass of monomer (d) represented by  
 $\text{CH}_2=\text{C}(\text{CH}_3)\text{COOCH}_2\text{CH}(\text{OH})\text{CH}_2\text{OH}$ .

25 (Composition II)

Copolymer containing:

8 to 13 parts by mass of monomer (a) represented by

$\text{CF}_3\text{CF}_2(\text{CF}_2\text{CF}_2)_n\text{CH}_2\text{CH}_2\text{OCOC}(\text{CH}_3)=\text{CH}_2$  (a mixture of compounds of  $n=3$  and  $n=4$  in a weight ratio of 5.4:1),

8 to 12 parts by mass of monomer (b) represented by  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COO}(\text{CH}_2\text{CH}_2\text{O})_9\text{CH}_3$ ,

5 4 to 9 parts by mass of monomer (b) represented by  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COO}(\text{CH}_2\text{CH}(\text{CH}_3)\text{O})_{12}\text{H}$ ,

0.5 to 3 parts by mass of monomer (c) represented by  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COOCH}_2\text{CH}(\text{OH})\text{CH}_2\text{Cl}$  and

0.3 to 2 parts by mass of monomer (d) represented by  
10  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COOCH}_2\text{CH}(\text{OH})\text{CH}_2\text{OH}$ .

(Composition III)

Copolymer containing:

5 to 8 parts by mass of monomer (a) represented by  $\text{CF}_3\text{CF}_2(\text{CF}_2\text{CF}_2)_n\text{CH}_2\text{CH}_2\text{OCOC}(\text{CH}_3)=\text{CH}_2$  (a mixture of compounds of  
15  $n=3$  and  $n=4$  in a weight ratio of 3.9:1),

14 to 17 parts by mass of monomer (b) represented by  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COO}(\text{CH}_2\text{CH}_2\text{O})_9\text{CH}_3$ ,

5 to 8 parts by mass of monomer (b) represented by  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COO}(\text{CH}_2\text{CH}(\text{CH}_3)\text{O})_{12}\text{H}$ ,

20 0.5 to 1.5 parts by mass of monomer (c) represented by  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COOCH}_2\text{CH}(\text{OH})\text{CH}_2\text{Cl}$  and

0.5 to 1.5 parts by mass of monomer (d) represented by  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COOCH}_2\text{CH}(\text{OH})\text{CH}_2\text{OH}$ .

Examples of commercial products of the copolymer are  
25 KP341 (trade name available from Shin-Etsu Chemical Co., Ltd.),  
POLYFLOW No.75 and POLYFLOW No.95 (trade name available from  
Kyoeisha Chemical Co., Ltd.), F TOP EF301, EF303, EF352 and EF204

(trade name available from Tokem Products Co., Ltd.), MEGAFAC F171 and F173 (trade name available from Dai-Nippon Ink and Chemicals Incorporated), Fluorad FC430 and FC431 (trade name available from Sumitomo Three M), Asahi Guard AG710, Surfron S-382, SC-101, 5 SC-102, SC-103, SC-104, SC-105 and SC-106 (trade name available from Asahi Glass Co., Ltd.) and the like. Those surfactants can be used alone or in a mixture of two or more thereof.

An amount of the surfactant is usually not more than 100 parts by mass, preferably not more than 70 parts by mass, particularly 10 preferably from 0.1 to 50 parts by mass based on 100 parts by mass of the sum of polymer components in the antireflection film material.

To the coating composition forming the antireflection layer (L2) of the present invention may be added, as case demands, a known acid.

15 The acid is added mainly for the purpose of adjusting a pH value of the coating composition to be not more than 4, preferably not more than 3, more preferably not more than 2.

By forming the antireflection layer (L2) with the acidic coating composition, diffusion and migration of the acid to the 20 antireflection layer (L2) from the photoresist layer (L1) after the exposure can be prevented and the resist pattern profile can be prevented from being in the form of T-top.

With respect to the acid to be used in the present invention, any of an organic acid and inorganic acid may be used. Preferred 25 examples of the organic acid are alkyl sulfonic acid, alkylbenzene sulfonic acid, alkylcarboxylic acid, alkylbenzenecarboxylic acid and partly fluorinated acids thereof. Preferred alkyl groups are those

having 1 to 20 carbon atoms. Those organic acids are used in an amount of usually from 0.1 to 2.0 % by mass, preferably from 0.5 to 1.0 % by mass in the composition.

Fluorine-containing organic acids may be  
5 fluoroalkylsulfonic acid and fluoroalkylcarboxylic acid having a fluorine chain of perfluoroalkyl group or hydrofluoroalkyl group, and the fluorine chain may be a linear or branched chain.

Examples of the fluoroalkyl group are not only those having 1 to 4 carbon atoms but also those having 5 to 15 carbon atoms.  
10 Other examples thereof are 1,1,2,2,3,3,4,4,5,5-decafluoropentyl group;  
1,1,2,2,3,3,4,4,5,5,6,6-decafluorohexyl group;  
1,1,2,2,3,3,4,4,5,5,6,6,7,7-tetradecafluoroheptyl group;  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8-hexadecafluorooctyl group;  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9-octadecafluorononyl group;  
15 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10-eicosafluorodecyl group;  
2-(perfluorononyl)ethyl group,  
2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11-eicosafluoroundecyl group,  
perfluorodecylmethyl group,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11-docosafluoroundecyl  
20 group, perfluoroundecyl group; 2-(perfluorodecyl)ethyl group,  
2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12-docosafluorododecyl  
group, perfluoroundecylmethyl group,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12-  
tetracosafuorododecyl group, perfluorododecyl group;  
25 2-(perfluoroundecyl)ethyl group,  
2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13-  
tetracosafuorotridecyl group, perfluorododecylmethyl group,

1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13-  
hexacosafuorotridecyl group, perfluorotridecyl group,  
2-(perfluorododecyl)ethyl group,  
2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13,14,14-  
5 hexacosafuorotetradecyl group, perfluorotridecylmethyl group,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13,14,14-  
octacosafuorotetradecyl group, perfluorotetradecyl group,  
2-(perfluorotridecyl)ethyl group,  
2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13,14,14,15,15-  
10 octacosafuoropentadecyl group, perfluorotetradecylmethyl group,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13,14,14,15,1  
5-triacontafuoropentadecyl group, perfluoropentadecyl group and the  
like.

Examples of such a fluoroalkylsulfonic acid are  
15 2-(perfluoropropyl)ethanesulfonic acid,  
1,1,2,2,3,3,4,4,5,5-decafluoropentanesulfonic acid,  
perfluoropentanesulfonic acid; 2-(perfluorobutyl)ethanesulfonic acid,  
1,1,2,2,3,3,4,4,5,5,6,6-dodecafluorohexanesulfonic acid,  
perfluorohexanesulfonic acid, 2-(perfluoropentyl)ethanesulfonic acid,  
20 1,1,2,2,3,3,4,4,5,5,6,6,7,7-tetradecafluoroheptanesulfonic acid,  
perfluoroheptanesulfonic acid; 2-(perfluorohexyl)ethanesulfonic acid,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8-hexadecafluorooctanesulfonic acid,  
perfluorooctanesulfonic acid; 2-(perfluoroheptyl)ethanesulfonic acid,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9-octadecafluorononanesulfonic acid,  
25 perfluorononanesulfonic acid; 2-(perfluorooctyl)ethanesulfonic acid,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10-eicosafuorodecanesulfonic  
acid, perfluorodecanesulfonic acid; 2-(perfluorononyl)ethanesulfonic

- acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11-  
docosafluoroundecanesulfonic acid, perfluoroundecanesulfonic acid;  
2-(perfluorodecyl)ethanesulfonic acid,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12-  
5 tetracosafuorododecanesulfonic acid, perfluorododecanesulfonic acid;  
2-(perfluoroundecyl)ethanesulfonic acid,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13-  
hexacosafuorotridecanesulfonic acid, perfluorotridecanesulfonic acid;  
2-(perfluorododecyl)ethanesulfonic acid,  
10 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13,14,14-  
octacosafuorotetradecanesulfonic acid, perfluorotetradecanesulfonic  
acid; 2-(perfluorotridecyl)ethanesulfonic acid,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13,14,14,15,1  
5-triacontafuoropentadecanesulfonic acid,  
15 perfluoropentadecanesulfonic acid and the like.

- Examples of fluoroalkylcarboxylic acid are  
2-(perfluoropropyl)ethanecarboxylic acid,  
1,1,2,2,3,3,4,4,5,5-decafluoropentanecarboxylic acid,  
perfluoropentanecarboxylic acid; 2-(perfluorobutyl)ethanecarboxylic  
20 acid, 1,1,2,2,3,3,4,4,5,5,6,6-dodecafluorohexanecarboxylic acid,  
perfluorohexanecarboxylic acid; 2-(perfluoropentyl)ethanecarboxylic  
acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7-tetradecafluoroheptanecarboxylic acid,  
perfluoroheptanecarboxylic acid; 2-(perfluorohexyl)ethanecarboxylic  
acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8-hexadecafluorooctanecarboxylic  
25 acid, perfluorooctanecarboxylic acid;  
2-(perfluoroheptyl)ethanecarboxylic acid,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9-octadecafluorononanecarboxylic

acid, perfluorononanecarboxylic acid;  
 2-(perfluorooctyl)ethanecarboxylic acid,  
 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10-eicosafluorodecanecarboxylic  
 acid, perfluorodecanecarboxylic acid;  
 5 2-(perfluorononyl)ethanecarboxylic acid,  
 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11-  
 docosafluoroundecanecarboxylic acid, perfluoroundecanecarboxylic  
 acid; 2-(perfluorodecyl)ethanecarboxylic acid,  
 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12-  
 10 tetracosafuorododecanecarboxylic acid, perfluorododecanecarboxylic  
 acid; 2-(perfluoroundecyl)ethanecarboxylic acid,  
 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13-  
 hexacosafuorotridecanecarboxylic acid, perfluorotridecanecarboxylic  
 acid; 2-(perfluorododecyl)ethanecarboxylic acid,  
 15 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13,14,14-  
 octacosafuorotetradecanecarboxylic acid,  
 perfluorotetradecanecarboxylic acid;  
 2-(perfluorotridecyl)ethanecarboxylic acid,  
 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13,14,14,15,1  
 20 5-triacontafuoropentadecanecarboxylic acid,  
 perfluoropentadecanecarboxylic acid and the like.

Those fluoroalkylsulfonic acids and fluoroalkylcarboxylic acids can be used alone or in a mixture of two or more thereof.

Preferred examples of the inorganic acid are sulfuric acid,  
 25 hydrochloric acid, nitric acid, phosphoric acid, hydrofluoric acid,  
 hydrobromic acid and the like. Those inorganic acids are preferred for  
 the purpose of adjusting a pH value of the coating composition to not

more than 4.0. The inorganic acid is usually used in an amount of from 0.01 to 0.2 % by mass based on the coating composition. The above-mentioned organic acids and inorganic acids may be used alone or in a mixture of two or more thereof.

5           To the coating composition forming the antireflection layer (L2) of the present invention may be added, as case demands, a water soluble polymer other than the fluorine-containing polymer (A). The water soluble polymer can be used for improving film forming property, and may be used within a range (kind and amount of the polymer)  
10       neither having an adverse effect on a refractive index of the coating film nor lowering transparency of the coating film.

          Examples of the water soluble polymer are, for instance, polyvinyl alcohols, polyalkyl vinyl ethers (polymethyl vinyl ether, polyethyl vinyl ether), polyacrylic acids, acrylate resins having carboxyl  
15       group, polymethacrylic acids, polyethylene glycols, celluloses and the like.

          An amount of the water soluble polymer is from 0.1 to 100 parts by mass, preferably from 0.5 to 50 parts by mass, more preferably from 1 to 30 parts by mass, particularly preferably from 1 to  
20       10 parts by mass based on 100 parts by mass of the fluorine-containing polymer (A) contained in the coating composition.

          To the coating composition forming the antireflection layer (L2) of the present invention may be added, as case demands, a known photoacid generator. The addition of the photoacid generator to the  
25       coating composition can prevent diffusion and migration of an acid to the antireflection layer (L2) from the photoresist layer (L1) after the exposure and the resist pattern profile can be prevented from being in



the form of T-top.

Examples of the acid generator are, for instance, onium salt, haloalkyl group-containing compound, o-quinonediazide compound, nitrobenzyl compound, sulfonic acid ester compound, sulfone  
5 compound and the like. Those acid generators can be used alone or in a mixture of two or more thereof. The preferred acid generator is onium salt.

An amount of the acid generator is usually not more than 20 parts by mass, preferably not more than 10 parts by mass,  
10 particularly preferably not more than 5 parts by mass based on 100 parts by mass of the fluorine-containing polymer (A) contained in the coating composition. If the amount of the acid generator is too large, there is a tendency that developing property of the laminated resist is lowered and transparency and a refractive index of the antireflection  
15 layer (L2) are deteriorated.

Also to the coating composition forming the antireflection layer (L2) of the present invention may be added, as case demands, a defoaming agent, light absorbing agent, storage stabilizer, antiseptic agent, adhesion promoter, photoacid generator, dye and the like.

20 In the coating composition forming the antireflection layer (L2) of the present invention, the content of the fluorine-containing polymer (A) having hydrophilic group varies depending on kind and molecular weight of the polymer, kind and amount of additives, kind of a solvent and the like, and is optionally selected so that a suitable  
25 viscosity being capable of forming a thin coating film is obtained. For example, the content of the polymer is from 0.1 to 50 % by mass, preferably from 0.5 to 30 % by mass, more preferably from 1 to 20 %

by mass, particularly preferably from 2 to 10 % by mass based on the whole coating composition.

The coating composition is applied on the photoresist layer (L1) to form the antireflection layer (L2). For the application, conventional methods are adopted. Examples of the suitable methods are rotary coating method, cast coating method, roll coating method and the like, and particularly a rotary coating method (spin coating method) is preferred. Other method of forming the antireflection layer (L2) is as mentioned infra.

Next, explained below are the method of forming the antireflection layer (L2) of the present invention on the photoresist layer (L1) to form the laminated photoresist and further one example of the method of forming a fine pattern using the laminated photoresist by means of the drawing.

Fig. 1 is a diagrammatic view for explaining each step (a) to (e) of the method of forming a fine pattern via the method of forming the laminated photoresist of the present invention.

(a) A step for forming the photoresist layer (L1):

First, as shown in Fig. 1(a), the photoresist composition is coated on a substrate L0 by a rotary coating method or the like in a coating thickness of from 0.01 to 5  $\mu\text{m}$ , preferably from 0.05 to 0.5  $\mu\text{m}$ , more preferably from 0.1 to 0.3  $\mu\text{m}$ .

Next, pre-baking treatment is carried out at a pre-determined temperature of not more than 150°C, preferably from 80° to 130°C to form the photoresist layer (L1).

Examples of the above-mentioned substrate are, for instance, a silicon wafer; a glass substrate; a silicon wafer or glass

substrate provided with an organic or inorganic antireflection film; a silicon wafer which has steps and is provided with various insulating films, electrode and wiring on a surface thereof; a mask blank; a semiconductor wafer of III-V group compound such as GaAs or AlGaAs  
5 and a semiconductor wafer of II-VI group compound; a piezoelectric wafer of crystal, quartz or lithium tantalate and the like.

In the present invention, conventional photoresist compositions can be used. There can be used, for example, a positive photoresist containing, as main components, novolak resin and  
10 diazonaphthoquinone (for g-line or i-line lithography), a chemically amplifying positive or negative resist prepared by using polyhydroxystyrene as a binder resin (for KrF lithography), a chemically amplifying positive photoresist prepared by using an acrylic polymer having an alicyclic structure at its side chain or an alicyclic  
15 polymer having a polynorbornene structure (for ArF lithography), a chemically amplifying positive photoresist prepared by using a fluorine-containing polymer (for F<sub>2</sub> lithography) and the like.

Since the antireflection layer (L2) of the present invention can realize a further lower refractive index as compared with  
20 conventional ones, it can be preferably applied especially to photography processes of a chemically amplifying positive photoresist using an acrylic polymer having an alicyclic structure at its side chain or an alicyclic polymer having a polynorbornene structure (ArF lithography) and a chemically amplifying positive photoresist prepared  
25 by using a fluorine-containing polymer (for F<sub>2</sub> lithography), and purposes such as precise pattern profile, high dimensional accuracy and repeatability thereof are achieved effectively.

(b) A step for forming the antireflection layer (L2):

As shown in Fig. 1(b), on the dried photoresist layer L1 is applied the coating composition containing the fluorine-containing polymer (A) by a rotary coating method. Then pre-baking is carried  
5 out, as case demands, to form the antireflection layer L2.

At that time, it is preferable that the thickness  $d_{\text{tarc}}$  of the antireflection layer L2 is adjusted to a thickness calculated by an equation:

10 
$$d_{\text{tarc}} = x \cdot \lambda / 4n_{\text{tarc}}$$

wherein  $d_{\text{tarc}}$  is a thickness (nm) of the antireflection layer;  $x$  is an odd number integer;  $\lambda$  is an exposure wavelength (nm);  $n_{\text{tarc}}$  is a refractive index measured at an exposure wavelength ( $\lambda$ ) of the antireflection  
15 layer, thereby exhibiting a reflection reducing effect at the upper interface of the resist film, namely lowering a reflectance and decreasing an influence of a standing wave.

The pre-baking conditions are optionally selected for the purpose of evaporating the residual solvent (B) in the antireflection  
20 layer L2 and forming a further uniform thin film. For example, the pre-baking temperature is selected within a range of from room temperature to 150°C, preferably from 40° to 120°C, more preferably from 60° to 100°C.

(c) An exposure step:

25 Subsequently as shown in Fig. 1(c), a pattern is drawn on the laminated photoresist (L1 + L2) by irradiating the photoresist with energy rays as shown by an arrow 13 through a mask 11 having a

desired pattern to selectively exposing a specific area 12.

In this case, examples of the energy rays (or chemical radiation) are, for instance, g-line (436 nm wavelength), i-line (365 nm wavelength), KrF excimer laser beam (248 nm wavelength), ArF excimer  
5 laser beam (193 nm wavelength), F<sub>2</sub> laser beam (157 nm wavelength) and the like. The energy ray is optionally selected depending on a photolithography process.

It is also possible to use, as an exposure light, X-ray, high energy electron beam, synchrotron radiation or the like or to scan  
10 electron beam, ion beam or the like without using the mask to directly expose the laminated photoresist to the pattern.

The reflection reducing effect of the present invention is exhibited most particularly when ArF excimer laser beam or F<sub>2</sub> laser beam is used as an exposure light.

15 Subsequently by carrying out post-exposure baking (PEB step) at a temperature of from 70° to 160°C, preferably from 90° to 140°C for about 30 seconds to about 10 minutes, a latent image 14 is formed on the exposed area 12 of the photoresist layer L1 as shown in Fig. 1(d). At this time, an acid generated by the exposing acts as a  
20 catalyst to decompose the dissolution-inhibiting group (protective group) and thereby solubility in a developing solution is increased and the exposed area of the resist film becomes soluble in a developing solution.

Also the antireflection layer L2 may be removed by rinsing  
25 with pure water or the like before carrying out the above-mentioned post-exposure baking (PEB step) or may be removed in the developing step after the PEB.

(d) Developing step:

Then when the photoresist layer L1 after the post-exposure baking is subjected to developing with a developing solution, the un-exposed area of the photoresist layer L1 remains on the substrate because its solubility in the developing solution is low but the exposed  
5 area 12 is dissolved in the developing solution as mentioned above.

On the other hand, the upper antireflection layer L2 is excellent in solubility in the developing solution irrespective of the exposed area and un-exposed area, and therefore even if it remains  
10 undissolved, it is removed together with the exposed portion in the developing step.

As the developing solution, an aqueous solution of 2.38 % by mass of tetramethylammonium hydroxide is preferably used. Also to the aqueous solution of 2.38 % by mass of tetramethylammonium  
15 hydroxide may be added a surfactant or alcohol such as methanol, ethanol, propanol or butanol in order to adjust wettability to the surfaces of antireflection layer L2 and photoresist layer L1.

Next, after flowing away the developing solution with pure water, lower alcohol or a mixture thereof, the substrate is dried and  
20 thus a desired resist pattern 15 can be formed as shown in Fig. 1(e).

Mentioned above is the explanation in the case of forming the laminated photoresist on the substrate L0, but the formation of the laminated photoresist is not limited to the case of forming the resist on a so-called substrate. The laminated photoresist may also be formed  
25 on a specific layer such as an electrically conductive film, insulating film or the like which is formed on the substrate. Also it is possible to form an antireflection film (lower antireflection layer), for example,

DUV-30, DUV-32, DUV-42 and DUV44 available from Brewer Science Co., Ltd. on the substrate. The laminated photoresist may be formed on a substrate treated with an adhesion improver.

Also when an intended fine pattern of an electrically  
5 conductive film or an insulating film is formed by using the so-formed fine resist pattern as a mask and etching a specific layer under the mask and then other steps are carried out, semiconductor devices and electronic devices can be produced. Since those steps are well known, explanation thereof is omitted.

10 The second of the present invention relates to the coating composition containing the fluorine-containing polymer having -COOH group and the water soluble solvent. This is a particularly preferred coating composition for more effectively and efficiently obtaining the above-mentioned antireflection film to be provided on the resist film.

15 Namely, the coating composition of the present invention contains:

(A1) a fluorine-containing polymer having carboxyl group and

(B) at least one solvent selected from the group consisting of water and alcohols, and

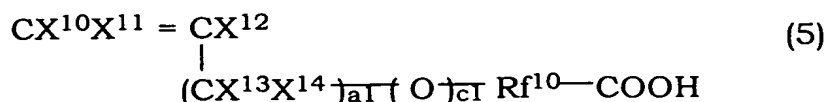
20 the fluorine-containing polymer (A1) has a number average molecular weight of from 10,000 to 750,000 and is represented by the formula (M-3):

- (M3) - (N3) -

(M-3)

25

wherein the structural unit M3 is a structural unit derived from a fluorine-containing monomer represented by the formula (5):



wherein  $\text{X}^{10}$  and  $\text{X}^{11}$  are the same or different and each is H or F;  $\text{X}^{12}$  is H, F, Cl,  $\text{CH}_3$  or  $\text{CF}_3$ ;  $\text{X}^{13}$  and  $\text{X}^{14}$  are the same or different and each is H or F;  $\text{Rf}^{10}$  is a divalent fluorine-containing alkylene group having 1 to 40 carbon atoms or a divalent fluorine-containing alkylene group having 2 to 100 carbon atoms and ether bond;  $a1$  and  $c1$  are the same or different and each is 0 or 1,

the structural unit N3 is a structural unit derived from a monomer copolymerizable with the fluorine-containing monomer of the formula (5), and

the structural units M3 and N3 are contained in amounts of from 55 to 100 % by mole and from 0 to 45 % by mole, respectively.

The coating composition of the present invention is featured especially by the fluorine-containing polymer (A1). Namely, by specifying the above-mentioned conditions with respect to the structure of the monomer (formula (5)) constituting the structural unit M3, the content of the structural unit M3 and the number average molecular weight of the polymer, the polymer stably dissolves in water or a solvent containing water, thin film forming property is good, and a good reflection reducing effect can be given to the resist film.

In the coating composition of the present invention, the fluorine-containing polymer (A1) contains the above-mentioned structural unit M3 as essential component and is a homopolymer of the monomer of the formula (5) or a copolymer of the monomer of the formula (5) with a monomer copolymerizable therewith.



It is important that the structural unit M3 has the fluorine-containing alkylene group  $Rf^{10}$  and  $-COOH$  group in its one side chain at the same time, and as a result, the both of hydrophilic property and a low refractive index can be imparted to the polymer.

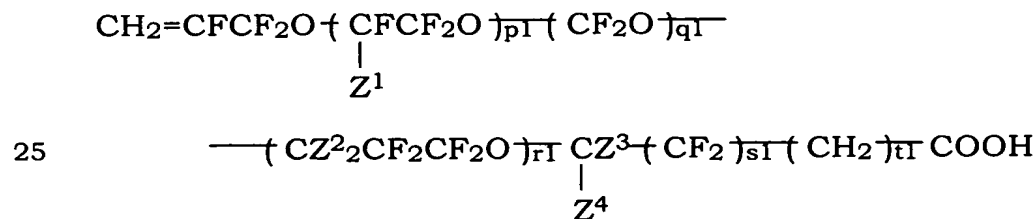
5 In the monomer of the formula (5) constituting the structural unit M3,  $Rf^{10}$  is a divalent fluorine-containing alkylene group having 1 to 40 carbon atoms or a divalent fluorine-containing alkylene group having 2 to 100 carbon atoms and ether bond. It is particularly preferable that  $Rf^{10}$  is a perfluoro alkylene group having 1  
10 to 40 carbon atoms or a divalent perfluoro alkylene group having 2 to 100 carbon atoms and ether bond, because a lower refractive index can be given to the polymer.

Examples of the fluorine-containing ethylenic monomer of the formula (5) having  $COOH$  group are fluorine-containing ethylenic  
15 monomers represented by the formula (5-1):



wherein  $Rf^{10}$  is as defined in the formula (5).

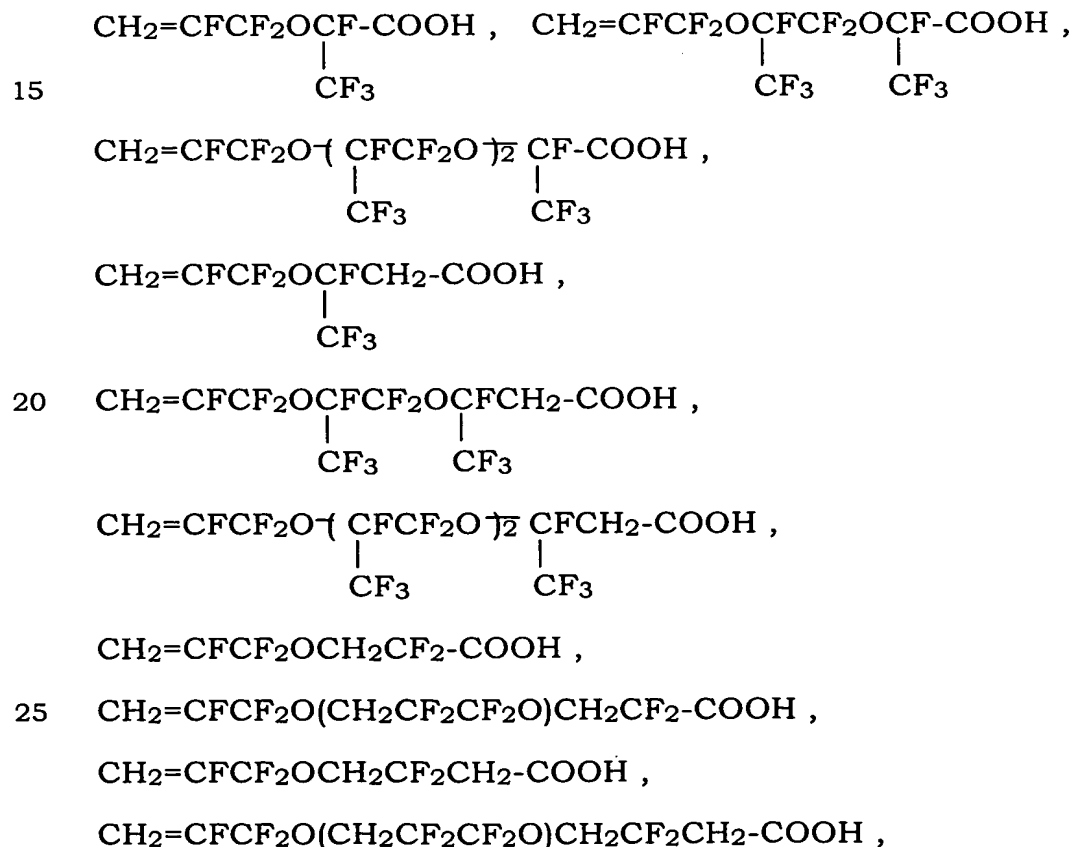
20 The monomers of the formula (5-1) are concretely fluorine-containing ethylenic monomers represented by:

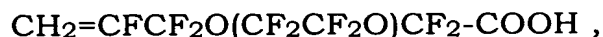
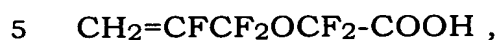
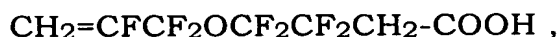


wherein  $Z^1$  is F or  $CF_3$ ;  $Z^2$  and  $Z^3$  are H or F;  $Z^4$  is H, F or  $CF_3$ ;  $p_1 + q_1 + r_1$  is 0 or an integer of 1 to 10;  $s_1$  is 0 or 1;  $t_1$  is 0 or an integer of 1 to 5; when both of  $Z^3$  and  $Z^4$  are H,  $p_1 + q_1 + r_1 + s_1$  is not 0. Those monomers are preferred since homopolymerizability thereof is excellent and more -COOH groups can be introduced to the fluorine-containing polymer, and as a result, good hydrophilic property can be given to the polymer and a low refractive index and excellent solubility in a developing solution can be imparted to the antireflection layer.

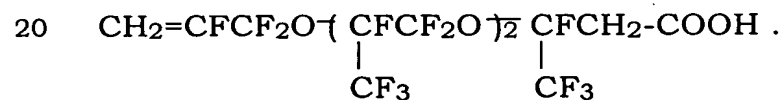
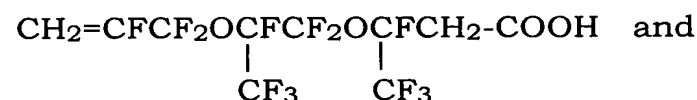
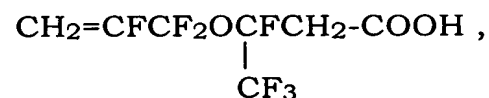
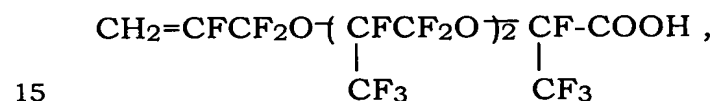
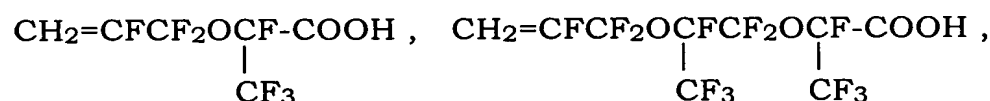
Also copolymerizability thereof with fluorine-containing ethylene such as tetrafluoroethylene or vinylidene fluoride is high and a lower refractive index can be imparted to the antireflection layer.

Preferred examples thereof are:





10 and the like, and particularly preferred are:

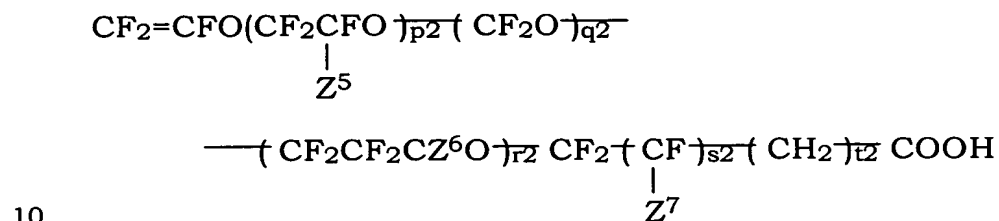


Further examples of the fluorine-containing ethylenic monomer of the formula (5) having -COOH group are  
25 fluorine-containing ethylenic monomers represented by the formula (5-2):



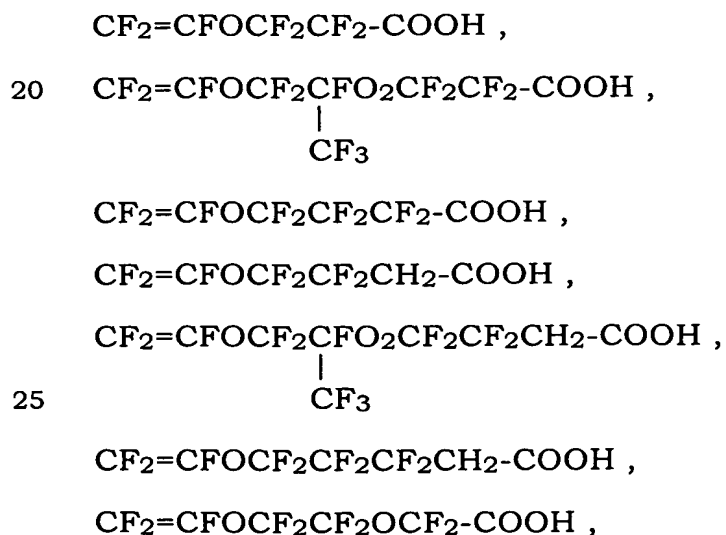
wherein  $\text{Rf}^{10}$  is as defined in the formula (5).

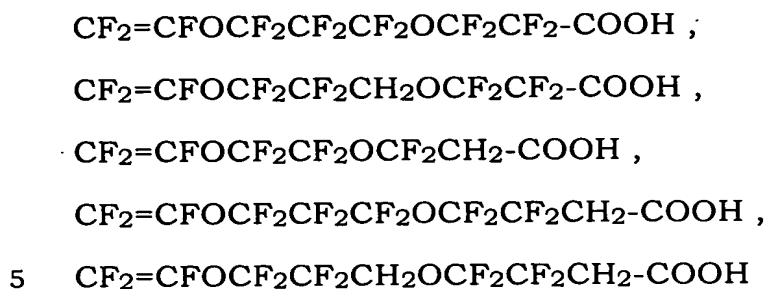
The monomers of the formula (5-2) are concretely  
5 fluorine-containing ethylenic monomers represented by:



wherein  $\text{Z}^5$  is F or  $\text{CF}_3$ ;  $\text{Z}^6$  is H or F;  $\text{Z}^7$  is H or F;  $p2 + q2 + r2$  is 0 or an integer of 1 to 10;  $s2$  is 0 or 1;  $t2$  is 0 or an integer of 1 to 5. Those monomers have high copolymerizability with fluorine-containing  
15 ethylene such as tetrafluoroethylene or vinylidene fluoride and can impart a lower refractive index to the antireflection layer.

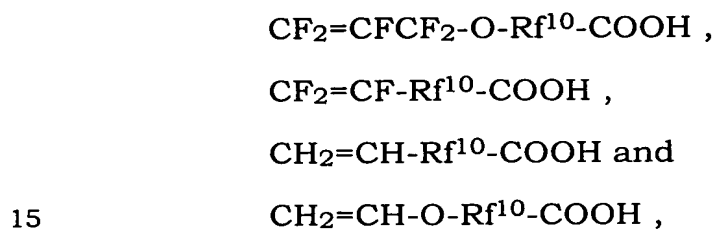
Preferred examples of the monomer of the formula (5-2) are:





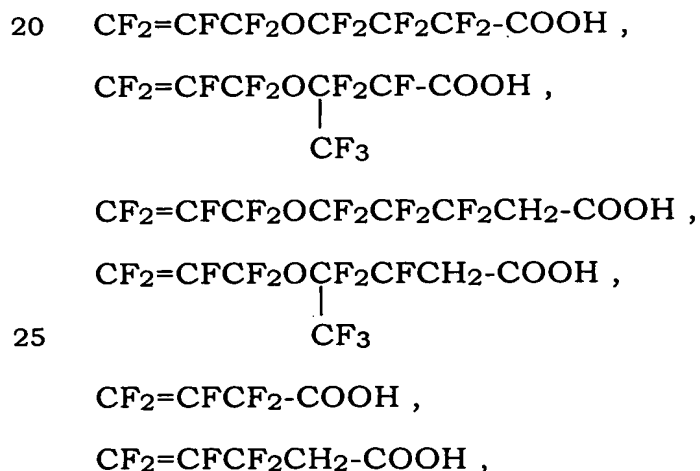
and the like.

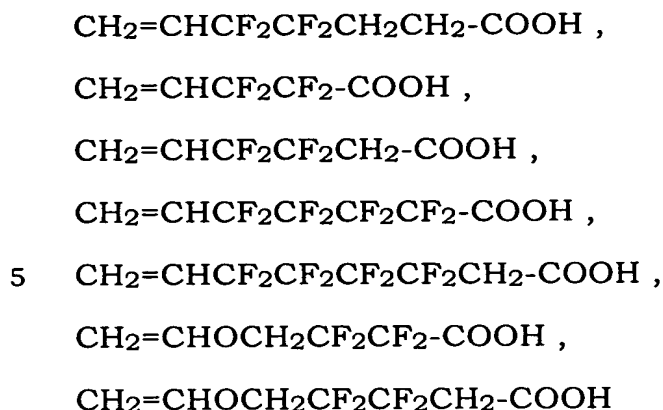
Other examples of the fluorine-containing ethylenic monomer of the formula (5) having -COOH group are  
10 fluorine-containing ethylenic monomers represented by:



wherein  $\text{Rf}^{10}$  is as defined in the formula (5).

Examples thereof are:





and the like.

10 In the case of a copolymer, the structural unit (N3) as a copolymerizable component can be optionally selected, but is preferably selected for the purpose of setting a refractive index low within a range of maintaining water solubility and solubility in a developing solution. Concretely the structural unit (N3) is selected  
15 from structural units derived from fluorine-containing ethylenic monomers.

Particularly preferred are those selected from structural units of the following (N3-1) and (N3-2).

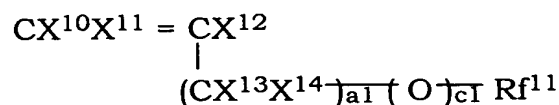
(N3-1) Structural units derived from fluorine-containing ethylenic  
20 monomers having 2 or 3 carbon atoms and at least one fluorine atom:

This structural unit N3-1 is preferred since a refractive index can be effectively set low and transparency can be improved without lowering solubility in a developing solution and also since a strength of the antireflection layer can be increased.

25 There are concretely exemplified  $\text{CF}_2=\text{CF}_2$ ,  $\text{CF}_2=\text{CFCl}$ ,  $\text{CH}_2=\text{CF}_2$ ,  $\text{CFH}=\text{CH}_2$ ,  $\text{CFH}=\text{CF}_2$ ,  $\text{CF}_2=\text{CFCF}_3$ ,  $\text{CH}_2=\text{CFCF}_3$ ,  $\text{CH}_2=\text{CHCF}_3$  and the like. Among them, from the viewpoint of good

copolymerizability and high effects of imparting transparency and a low refractive index, tetrafluoroethylene ( $\text{CF}_2=\text{CF}_2$ ), chlorotrifluoroethylene ( $\text{CF}_2=\text{CFCl}$ ) and vinylidene fluoride ( $\text{CH}_2=\text{CF}_2$ ) are preferred.

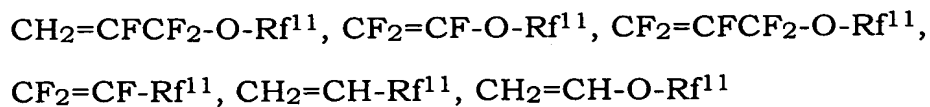
(N3-2) Structural units derived from monomers represented by the  
5 formula (n3-2):



10 wherein  $\text{X}^{10}$ ,  $\text{X}^{11}$ ,  $\text{X}^{12}$ ,  $\text{X}^{13}$ ,  $\text{X}^{14}$ ,  $a1$  and  $c1$  are as defined in the formula (5);  $\text{Rf}^{11}$  is a fluorine-containing alkyl group having 1 to 40 carbon atoms or a fluorine-containing alkyl group having 2 to 100 carbon atoms and ether bond.

Those structural units are preferred since a refractive index  
15 can be decreased effectively and transparency can be improved.

Preferred examples are:



20

and the like, wherein  $\text{Rf}^{11}$  is as defined in the formula (n3-2).

The proportions of each structural unit of the fluorine-containing polymer of the formula (M-3) are optionally selected depending on the above-mentioned preferred fluorine content and  
25 hydrophilic group content. A higher content of the structural unit M3 is preferred because water solubility is enhanced when a composition contains water, and also because a mixing ratio of alcohol can be

decreased when solubility of the polymer (A1) is increased by mixing alcohol.

With respect to the proportions of components of the fluorine-containing polymer (A1) used for the coating composition of the present invention, the structural unit M3 and structural unit N3  
5 are contained in amounts of from 55 to 100 % by mole and from 0 to 45 % by mole, preferably from 60 to 100 % by mole and from 0 to 40 % by mole, more preferably from 70 to 100 % by mole and from 0 to 30 % by mole, particularly preferably from 80 to 100 % by mole and from 0  
10 to 20 % by mole.

Also among the monomers of the formula (5), in the case of homopolymerizable monomer, the homopolymer obtained therefrom is more preferred since water solubility of the fluorine-containing polymer (A1) and a dissolution rate of the antireflection film in a developing  
15 solution can be enhanced. Even in the case of the above-mentioned proportion of the structural unit M3, a low refractive index and transparency can be maintained by using the above-exemplified fluorine-containing monomers.

It is important that the number average molecular weight of the fluorine-containing polymer of the formula (M-3) is from 10,000 to 750,000, which enables the fluorine-containing polymer (A1) to stably  
20 maintain its hydrophilic property.

The number average molecular weight is preferably from 20,000 to 500,000, more preferably from 31,000 to 300,000,  
25 particularly preferably from 40,000 to 200,000.

If the number average molecular weight is too low, hydrophilic property of the fluorine-containing polymer (A1) is lowered,



and in order to make the polymer soluble in a solvent containing water, much amount of alcohol solvent need be mixed. Therefore when forming the antireflection film on the resist film, a reflection reducing effect is lowered due to an intermixing phenomenon at an interface  
5 between them. Further the dissolution rate of the coated antireflection film in a developing solution is decreased and resolution of the resist is lowered.

On the contrary, if the molecular weight of the fluorine-containing polymer (A1) is too high, film forming property of  
10 the antireflection film is lowered and it becomes difficult to form a uniform thin film.

In the coating composition of the present invention, the solvent (B) is at least one selected from the group consisting of water and alcohols.

15 It is preferable that the solvent (B) is selected from solvents which do not re-dissolve the previously formed lower photoresist film when the coating composition is applied. From this point of view, the solvent (B) is preferably water and/or alcohols. Further it is preferable that the solvent is water alone or a solvent mixture of water  
20 and alcohol. It is particularly preferable that alcohols are not used as far as possible or a solvent mixture containing alcohol at a low ratio is used.

The fluorine-containing polymer (A1) of the present invention has good solubility in those water, alcohols and solvent  
25 mixture of water and alcohol.

Among the solvents (B), water is not limited particularly. Preferred are distilled water, ion exchange water, water subjected to

filtration and water subjected to adsorption treatment to remove organic impurities and metal ion.

Alcohols are optionally selected from those which do not re-dissolve the lower photoresist layer (L1), depending on kind of the photoresist layer (L1). Generally lower alcohols having 1 to 6 carbon atoms are preferred, and concretely methanol, ethanol, isopropanol, n-propanol, butyl alcohols and the like are preferred.

When using a solvent mixture of water and alcohol, it is preferable that the mixing ratio of water is more than 60 % by mass, more preferably more than 65 % by mass, particularly preferably more than 70 % by mass, further preferably more than 75 % by mass based on the total amount of water and alcohol.

In addition to the solvent (B), a water soluble organic solvent may be used together for the purpose of improving coatability, etc. within a range not re-dissolving the photoresist layer (L1).

A water soluble organic solvent is not limited particularly as far as it dissolves in water in an amount of not less than 1 % by mass. Examples thereof are, for instance, ketones such as acetone and methyl ethyl ketone; esters of acetic acids such as methyl acetate and ethyl acetate; polar solvents such as dimethylformamide, dimethyl sulfoxide, methyl cellosolve, cellosolve acetate, butyl cellosolve, butyl carbitol and carbitol acetate; and the like.

An adding amount of the water soluble organic solvent to be added in addition to water or alcohol is from 0.1 to 30 % by mass, preferably from 0.5 to 20 % by mass, more preferably from 1 to 10 % by mass, particularly preferably from 1 to 5 % by mass based on the total amount of solvents (B).

To the coating composition of the present invention may be added, as case demands, at least one selected from basic substances, for example, ammonia and organic amines. In this case, a part or the whole of -COOH groups in the fluorine-containing polymer (A1) may be, for example, in the form of salt such as ammonium salt or amine salt.

The addition of the basic substance is effective for enhancing water solubility and solubility in a developing solution and also for maintaining repeatability of the dissolution rate in a developing solution. Also it is effective for adjusting the pH value of the coating composition to be within an optimum range.

Further in the present invention, water solubility of the fluorine-containing polymer (A1) can be improved, and for example, even in the case of using a solvent mixture of water and alcohol, a mixing ratio of alcohol can be decreased and the polymer can be dissolved in a solvent containing water at a high mixing ratio or can be dissolved in a solvent of water only not containing alcohols.

With respect to organic amines, preferred are water soluble organic amine compounds. Preferred examples thereof are, for instance, primary amines such as methylamine, ethylamine, propylamine, butylamine and cyclohexylamine; secondary amines such as dimethylamine, diethylamine, dipropylamine and dibutylamine; tertiary amines such as trimethylamine, triethylamine, tripropylamine, tributylamine, pyridine, pyrrole, piperidine, oxazole and morpholine; hydroxylamines such as monoethanolamine, propanolamine, diethanolamine, triethanolamine and tris(hydroxymethyl)aminomethane; quaternary ammonium compounds such as tetramethylammonium hydroxide, tetraethylammonium

hydroxide, tetrapropylammonium hydroxide and tetrabutylammonium hydroxide; primary, secondary and tertiary polyamines such as ethylenediamine, diethylenediamine, tetraethylenediamine, diethylenetriamine, tetraethylenetriamine, imidazole, imidazolidine, pyrazine and s-triazine ; and the like.

Among them, from the point of maintaining a low refractive index, increasing the dissolution rate in a developing solution and improving water solubility, preferred are hydroxylamines such as monoethanolamine, propanolamine, diethanolamine, triethanolamine and tris(hydroxymethyl)aminomethane, and particularly preferred is monoethanolamine.

In the coating composition of the present invention, ammonia or organic amine can be added usually in an amount of from 0.01 to 10 mole, preferably from 0.1 to 5 mole, more preferably from 0.1 to 2 mole, particularly preferably from 0.4 to 1 mole based on 1 mole of hydrophilic group of the fluorine-containing polymer (A1) to be used.

To the coating composition of the present invention may be added, as case demands, a known surfactant.

The addition of a surfactant is effective for improving wettability of the coating composition to the surface of the lower photoresist layer and for forming a uniform thin film, and further is preferred for decreasing a surface tension of the obtained antireflection layer after the coating, thereby stabilizing solubility in a developing solution. Further the addition of a surfactant is preferred for preventing striation.

Also in the present invention, water solubility of the

fluorine-containing polymer (A1) can be improved. For example, even in the case of using a solvent mixture of water and alcohol, a mixing ratio of alcohol can be decreased and the polymer can be dissolved in a solvent containing water at a higher mixing ratio or can be dissolved in  
5 a solvent of water only not containing alcohols.

Examples of the surfactant to be added are nonionic surfactants, anionic surfactants and ampholytic surfactants, and anionic surfactants are used preferably.

Examples of nonionic surfactants are polyoxyethylene alkyl  
10 ethers, for instance, polyoxyethylene lauryl ether, polyoxyethylene stearyl ether, polyoxyethylene oleyl ether, polyoxyethylene cetyl ether, polyoxyethylene octylphenyl ether, polyoxyethylene nonylphenyl ether, polyethylene glycol dilaurate and polyethylene glycol distearate; polyoxyethylene fatty acid diester, polyoxy fatty acid monoester,  
15 polyoxyethylene/polyoxypropylene block polymer, acetylene glycol derivative and the like.

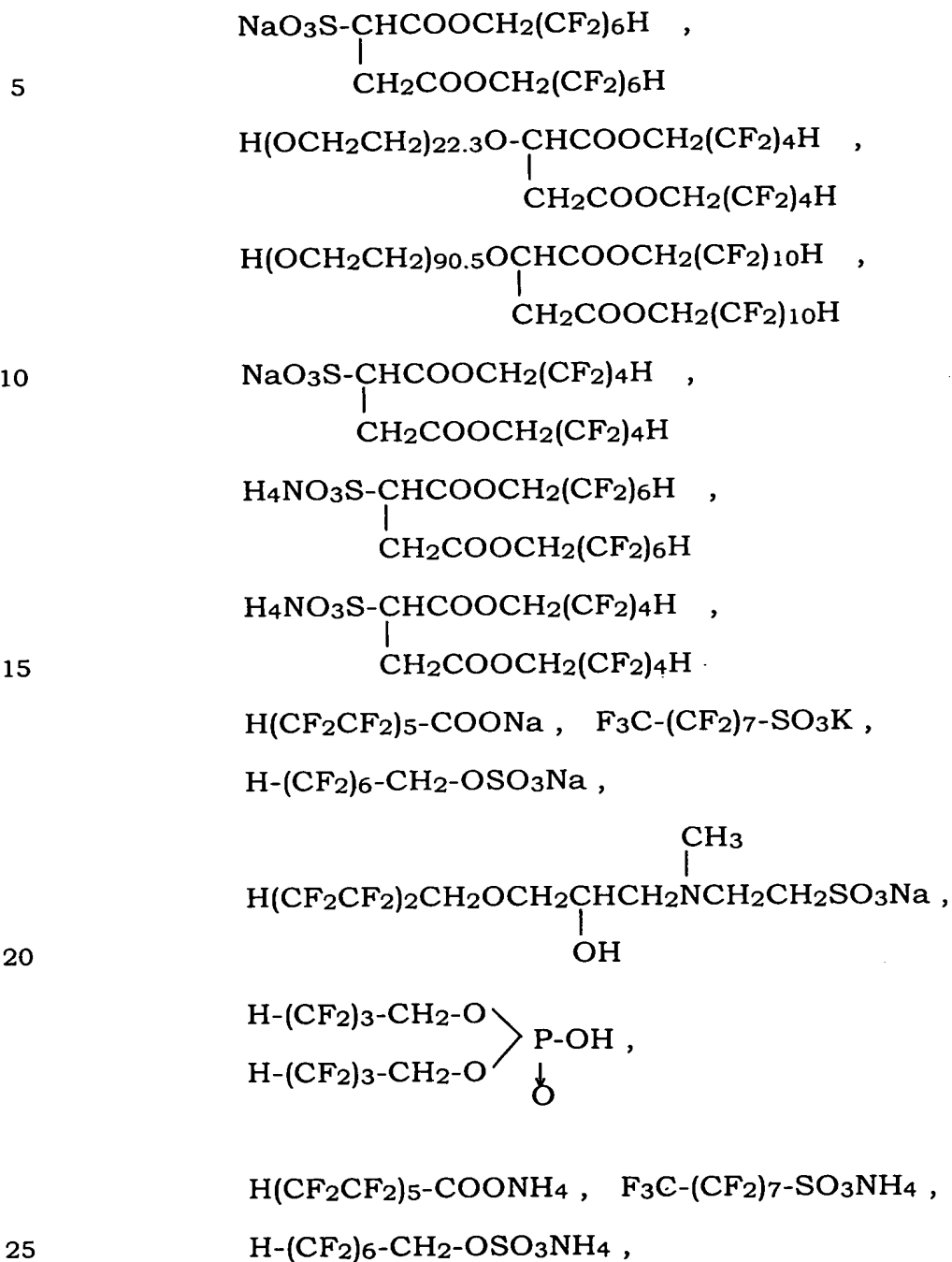
Examples of the anionic surfactants are alkyl diphenylether disulfonic acid and its ammonium salt or organic amine salt; alkyl diphenylether sulfonic acid and its ammonium salt or organic amine  
20 salt; alkylbenzene sulfonic acid and its ammonium salt or organic amine salt; polyoxyethylene alkyl ether sulfuric acid and its ammonium salt or organic amine salt; alkyl sulfuric acid and its ammonium salt or organic amine salt; and the like.

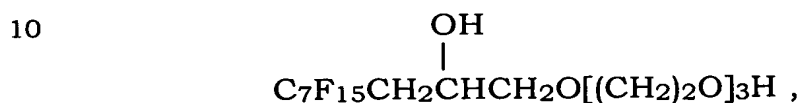
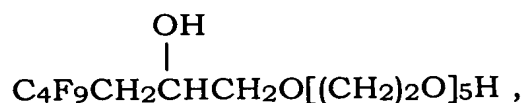
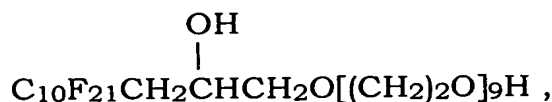
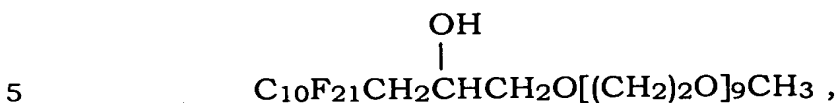
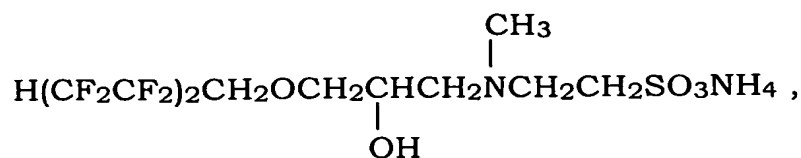
Examples of ampholytic surfactants are  
25 2-alkyl-N-carboxymethyl-N-hydroxyethyl imidazolinium betaine, lauric acid amidopropylhydroxysulfone betaine and the like.

Also fluorine-containing surfactants are preferred because a

low refractive index of the antireflection layer can be maintained.

Examples thereof are:





and the like

20 With respect to the fluorine-containing surfactants, not only the above-mentioned low molecular weight compounds but also the following high molecular weight compounds are preferred because a low refractive index of the antireflection layer (L2) can be maintained.

25 There are concretely copolymers having a number average molecular weight of 1,000 to 500,000 and containing component units derived from (a) acrylic ester or methacrylic acid ester having fluoroalkyl group (monomer (a)), (b) polyalkylene glycol acrylate or

polyalkylene glycol methacrylate (monomer (b)), (c) 3-chloro-2-hydroxypropyl (meth)acrylate (monomer (c)) and (d) glycerol mono(meth)acrylate (monomer (d)) and fluorine-containing polymer surfactants containing such a copolymer.

5           The monomers providing each component unit are explained below.

Examples of the monomer (a) are, for instance, one or two or more compounds represented by the formula:



wherein  $Rf^{20}$  is a linear or branched perfluoroalkyl group having 3 to 20 carbon atoms;  $R^{11}$  is hydrogen atom or methyl;  $R^{10}$  is a linear or branched alkylene group having 1 to 10 carbon atoms,  $-SO_2N(R^{12})R^{13}$ -  
15   group ( $R^{12}$  is an alkyl group having 1 to 10 carbon atoms;  $R^{13}$  is a linear or branched alkylene group having 1 to 10 carbon atoms) or  $-CH_2CH(OR^{14})CH_2-$  group ( $R^{14}$  is hydrogen atom or an acyl group having 1 to 10 carbon atoms).

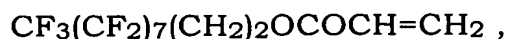
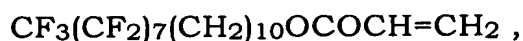
Preferred examples of the monomer (a) are as follows.

20   Those monomers may be used alone or in a mixture of two or more thereof.

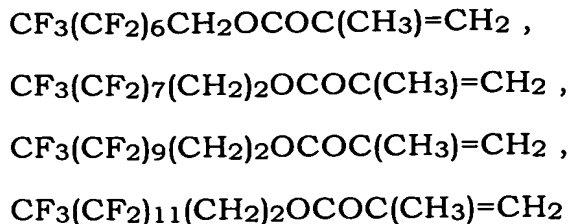
(a-1)  $CF_3(CF_2)_n(CH_2)_mOCOCR^{11}=CH_2$  ( $R^{11}$  is hydrogen atom or methyl;  $n$  is an integer of 2 to 19,  $m$  is an integer of 1 to 10)

Examples thereof are:

25







5

and the like.

(a-2)  $(\text{CF}_3)_2\text{CF}(\text{CF}_2)_n(\text{CH}_2)_m\text{OCOCR}^{11}=\text{CH}_2$  ( $\text{R}^{11}$  is hydrogen atom or methyl;  $n$  is 0 or an integer of 1 to 17,  $m$  is an integer of 1 to 10)

Examples thereof are:

10

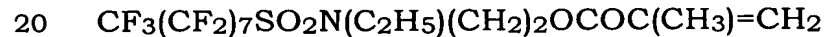
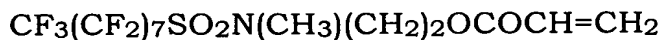


and the like.

(a-3)  $\text{CF}_3(\text{CF}_2)_n\text{SO}_2\text{N}(\text{R}^{12})(\text{CH}_2)_m\text{OCOCR}^{11}=\text{CH}_2$  ( $\text{R}^{11}$  is hydrogen atom or methyl;  $\text{R}^{12}$  is an alkyl group having 1 to 10 carbon atoms;  $n$  is an integer of 2 to 19,  $m$  is an integer of 1 to 10)

15

Examples thereof are:

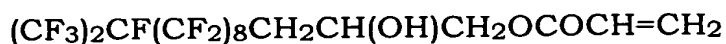


and the like.

(a-4)  $(\text{CF}_3)_2\text{CF}(\text{CF}_2)_n\text{CH}_2\text{CH}(\text{OR}^{14})(\text{CH}_2)_m\text{OCOCR}^{11}=\text{CH}_2$  ( $\text{R}^{11}$  is hydrogen atom or methyl;  $\text{R}^{14}$  is hydrogen atom or an acyl group having 1 to 10 carbon atoms;  $n$  is 0 or an integer of 1 to 17,  $m$  is an integer of 1 to 10)

25

Examples thereof are:



and the like.

- 5                   It is preferable that the monomer (b) is, for instance, one or two or more compounds represented by the formula:



- 10   wherein  $\text{R}^{15}$  and  $\text{R}^{17}$  are hydrogen atom or methyl;  $\text{R}^{16}$  is an alkylene group having 2 to 6 carbon atoms,  $n$  is an integer of 3 to 50.

- Usually  $-\text{CH}_2\text{CH}_2-$  is suitable as  $\text{R}^{16}$ .  $\text{R}^{16}$  may be  $-\text{CH}(\text{CH}_3)\text{CH}_2-$ ,  $-\text{CH}(\text{C}_2\text{H}_5)\text{CH}_2-$  or the like. Namely, in the present invention, polyethylene glycol acrylate or methacrylate in which  $\text{R}^{16}$  is  
15  $-\text{CH}_2\text{CH}_2-$  can be used particularly preferably. Also,  $n$  is selected from integers of 3 to 50, and usually when  $n$  is selected from integers of 9 to 25, especially good result can be obtained. It is a matter of course that the monomer (b) may be in the form of a mixture of two or more monomers having different kind of  $\text{R}^{16}$  and different number of  $n$ .

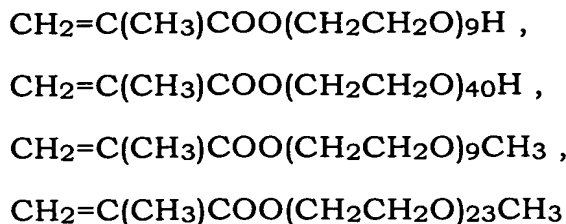
- 20                   Examples of the monomer (b) are as follows. Those monomers may be used alone or in a mixture of two or more thereof.

(b-1)  $\text{CH}_2=\text{CR}^{15}\text{COO}(\text{CH}_2\text{CH}_2\text{O})_n\text{R}^{17}$  ( $\text{R}^{15}$  and  $\text{R}^{17}$  are hydrogen atom or methyl;  $n$  is an integer of 3 to 50)

Examples thereof are:

25





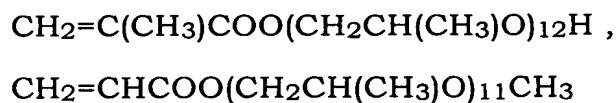
5

and the like.

(b-2)  $\text{CH}_2=\text{CR}^{15}\text{COO}(\text{CH}_2\text{CH}(\text{CH}_3)\text{O})_n\text{R}^{17}$  ( $\text{R}^{15}$  and  $\text{R}^{17}$  are hydrogen atom or methyl;  $n$  is an integer of 3 to 50)

Examples thereof are:

10



and the like.

15 (b-3)  $\text{CH}_2=\text{CR}^{15}\text{COO}(\text{CH}_2\text{CH}_2\text{O})_n(\text{CH}_2\text{CH}(\text{CH}_3)\text{O})_m\text{R}^{17}$  ( $\text{R}^{15}$  and  $\text{R}^{17}$  are hydrogen atom or methyl;  $n + m$  is an integer of 3 to 50)

Examples thereof are:



20

and the like.

3-Chloro-2-hydroxypropyl (meth)acrylate of the monomer (c) is 3-chloro-2-hydroxypropyl acrylate and/or 3-chloro-2-hydroxypropyl methacrylate represented by:

25



wherein  $R^{18}$  is hydrogen atom or methyl.

Glycerol mono(meth)acrylate of the monomer (d) is glycerol monoacrylate and/or glycerol monomethacrylate represented by:



wherein  $R^{19}$  is hydrogen atom or methyl.

In the copolymer to be used in the present invention as a fluorine-containing polymer surfactant, a copolymerization ratio of the  
10 (meth)acrylic acid ester (monomer (a)) having fluoroalkyl group is at least 5 % by mass, preferably from 6 to 70 % by mass.

A copolymerization ratio of the polyalkylene glycol (meth)acrylate (monomer (b)) is at least 10 % by mass, preferably from 14 to 60 % by mass. If the ratio is less than 10 % by mass,  
15 dispersibility in water tends to be lowered.

A copolymerization ratio of the 3-chloro-2-hydroxypropyl (meth)acrylate (monomer (c)) is at least 0.5 % by mass, preferably from 0.5 to 30 % by mass. A copolymerization ratio of the glycerol mono(meth)acrylate (monomer (d)) is at least 0.5 % by mass, preferably  
20 from 0.5 to 30 % by mass.

It is preferable that a total amount of 3-chloro-2-hydroxypropyl (meth)acrylate (monomer (c)) and glycerol mono(meth)acrylate (monomer (d)) is at least 1 % by mass, preferably from 1.2 to 30 % by mass. Also it is preferable that a ratio of  
25 3-chloro-2-hydroxypropyl (meth)acrylate (monomer (c)) to the sum of monomer (c) and monomer (d) is from 10 to 90 % by mass, particularly from 20 to 80 % by mass.

A number average molecular weight of the fluorine-containing polymer surfactant is from 1,000 to 500,000, preferably from 5,000 to 200,000. If it is less than 1,000, durability tends to be lowered, and if it exceeds 500,000, there is a case where a viscosity of the surfactant solution becomes high and workability is lowered. The fluorine-containing polymer surfactant may be a random copolymer or a block copolymer.

With respect to those copolymers to be used as the fluorine-containing polymer surfactant, besides the monomers (a), (b), (c) and (d) can be copolymerized a copolymerizable monomer having no fluoroalkyl group such as ethylene, vinyl chloride, halogenated vinylidene, styrene, (meth)acrylic acid, alkyl ester of (meth)acrylic acid, benzyl methacrylate, vinyl alkyl ketone, vinyl alkyl ether, isoprene, chloroprene, maleic anhydride or butadiene. When those other monomers are copolymerized, dispersibility, uniform coatability, water- and oil-repellency and durability can be enhanced and a low refractive index can be obtained. Also other various properties such as solubility and water resistance can be optionally improved. A copolymerization ratio of the comonomer having no fluoroalkyl group is from 0 to 40 % by mass, preferably from 0 to 20 % by mass.

The copolymer suitable as the fluorine-containing polymer surfactant of the present invention contains, for example, the following copolymerizable components, but the composition of the copolymer is not limited to them.

(Composition I)

Copolymer containing:

19 to 22 parts by mass of monomer (a) represented by

$\text{CF}_3\text{CF}_2(\text{CF}_2\text{CF}_2)_n\text{CH}_2\text{CH}_2\text{OCOC}(\text{CH}_3)=\text{CH}_2$  (a mixture of compounds of  $n=3$ ,  $n=4$  and  $n=5$  in a weight ratio of 5:3:1),

8 to 13 parts by mass of monomer (b) represented by  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COO}(\text{CH}_2\text{CH}_2\text{O})_9\text{CH}_3$ ,

5 4 to 7 parts by mass of monomer (b) represented by  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COO}(\text{CH}_2\text{CH}(\text{CH}_3)\text{O})_{12}\text{H}$ ,

3 to 5 parts by mass of monomer (c) represented by  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COOCH}_2\text{CH}(\text{OH})\text{CH}_2\text{Cl}$  and

1 to 2 parts by mass of monomer (d) represented by  
10  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COOCH}_2\text{CH}(\text{OH})\text{CH}_2\text{OH}$ .

(Composition II)

Copolymer containing:

8 to 13 parts by mass of monomer (a) represented by  $\text{CF}_3\text{CF}_2(\text{CF}_2\text{CF}_2)_n\text{CH}_2\text{CH}_2\text{OCOC}(\text{CH}_3)=\text{CH}_2$  (a mixture of compounds of  
15  $n=3$  and  $n=4$  in a weight ratio of 5.4:1),

8 to 12 parts by mass of monomer (b) represented by  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COO}(\text{CH}_2\text{CH}_2\text{O})_9\text{CH}_3$ ,

4 to 9 parts by mass of monomer (b) represented by  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COO}(\text{CH}_2\text{CH}(\text{CH}_3)\text{O})_{12}\text{H}$ ,

20 0.5 to 3 parts by mass of monomer (c) represented by  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COOCH}_2\text{CH}(\text{OH})\text{CH}_2\text{Cl}$  and

0.3 to 2 parts by mass of monomer (d) represented by  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COOCH}_2\text{CH}(\text{OH})\text{CH}_2\text{OH}$ .

(Composition III)

25 Copolymer containing:

5 to 8 parts by mass of monomer (a) represented by  $\text{CF}_3\text{CF}_2(\text{CF}_2\text{CF}_2)_n\text{CH}_2\text{CH}_2\text{OCOC}(\text{CH}_3)=\text{CH}_2$  (a mixture of compounds of

n=3 and n=4 in a weight ratio of 3.9:1),

14 to 17 parts by mass of monomer (b) represented by  
 $\text{CH}_2=\text{C}(\text{CH}_3)\text{COO}(\text{CH}_2\text{CH}_2\text{O})_9\text{CH}_3$ ,

5 5 to 8 parts by mass of monomer (b) represented by  
 $\text{CH}_2=\text{C}(\text{CH}_3)\text{COO}(\text{CH}_2\text{CH}(\text{CH}_3)\text{O})_{12}\text{H}$ ,

0.5 to 1.5 parts by mass of monomer (c) represented by  
 $\text{CH}_2=\text{C}(\text{CH}_3)\text{COOCH}_2\text{CH}(\text{OH})\text{CH}_2\text{Cl}$  and

0.5 to 1.5 parts by mass of monomer (d) represented by  
 $\text{CH}_2=\text{C}(\text{CH}_3)\text{COOCH}_2\text{CH}(\text{OH})\text{CH}_2\text{OH}$ .

10                Examples of commercial products of the copolymer are  
KP341 (trade name available from Shin-Etsu Chemical Co., Ltd.),  
POLYFLOW No.75 and POLYFLOW No.95 (trade name available from  
Kyoisha Chemical Co., Ltd.), F TOP EF301, EF303, EF352 and EF204  
(trade name available from Tokem Products Co., Ltd.), MEGAFAC F171  
15 and F173 (trade name available from Dai-Nippon Ink and Chemicals  
Incorporated), Fluorad FC430 and FC431 (trade name available from  
Sumitomo Three M), Asahi Guard AG710, Surfron S-382, SC-101,  
SC-102, SC-103, SC-104, SC-105 and SC-106 (trade name available  
from Asahi Glass Co., Ltd.) and the like. Those surfactants can be  
20 used alone or in a mixture of two or more thereof.

                 An amount of the surfactant is usually not more than 100  
parts by mass, preferably not more than 70 parts by mass, particularly  
preferably from 0.01 to 50 parts by mass, especially from 0.1 to 30  
parts by mass, further from 0.5 to 20 parts by mass based on the total  
25 parts by mass of polymer components in the antireflection film  
material.

                 To the coating composition of the present invention may be

added, as case demands, a known acid.

The acid is added mainly for the purpose of adjusting a pH value of the coating composition to be not more than 4, preferably not more than 3, more preferably not more than 2.

5 By forming the antireflection layer (L2) with the acidic coating composition, diffusion and migration of an acid to the antireflection layer from the photoresist layer after the exposure can be prevented and the resist pattern profile can be prevented from being in the form of T-top.

10 With respect to the acid to be used in the present invention, any of an organic acid and inorganic acid may be used. Preferred examples of the organic acid are alkylsulfonic acid, alkylbenzenesulfonic acid, alkylcarboxylic acid, alkylbenzenecarboxylic acid and partly fluorinated acids thereof. Preferred alkyl groups are  
15 those having 1 to 20 carbon atoms. Those organic acids are used in an amount of usually from 0.1 to 2.0 % by mass, preferably from 0.5 to 1.0 % by mass in the composition.

Fluorine-containing organic acids may be fluoroalkylsulfonic acid and fluoroalkylcarboxylic acid having a fluorine  
20 chain of perfluoroalkyl group or hydrofluoroalkyl group, and the fluorine chain may be a linear or branched chain.

Examples of the fluoroalkyl group are not only those having 1 to 4 carbon atoms but also those having 5 to 15 carbon atoms. Other examples thereof are 1,1,2,2,3,3,4,4,5,5-decafluoropentyl group;  
25 1,1,2,2,3,3,4,4,5,5,6,6-decafluorohexyl group;  
1,1,2,2,3,3,4,4,5,5,6,6,7,7-tetradecafluoroheptyl group;  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8-hexadecafluorooctyl group;



- 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9-octadecafluorononyl group;  
 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10-eicosafluorodecyl group;  
 2-(perfluorononyl)ethyl group;  
 2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11-eicosafluoroundecyl group;  
 5 perfluorodecylmethyl group;  
 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11-docosafluoroundecyl  
 group, perfluoroundecyl group; 2-(perfluorodecyl)ethyl group,  
 2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12-docosafluorododecyl  
 group, perfluoroundecylmethyl group,  
 10 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12-  
 tetracosafuorododecyl group, perfluorododecyl group;  
 2-(perfluoroundecyl)ethyl group,  
 2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13-  
 tetracosafuorotridecyl group, perfluorododecylmethyl group,  
 15 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13-  
 hexacosafuorotridecyl group, perfluorotridecyl group,  
 2-(perfluorododecyl)ethyl group,  
 2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13,14,14-  
 hexacosafuorotetradecyl group, perfluorotridecylmethyl group,  
 20 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13,14,14-  
 octacosafuorotetradecyl group, perfluorotetradecyl group,  
 2-(perfluorotridecyl)ethyl group,  
 2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13,14,14,15,15-  
 octacosafuoropentadecyl group, perfluorotetradecylmethyl group,  
 25 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13,14,14,15,1  
 5-triacontafuoropentadecyl group, perfluoropentadecyl group and the  
 like.

Examples of such a fluoroalkylsulfonic acid are

- 2-(perfluoropropyl)ethanesulfonic acid,  
1,1,2,2,3,3,4,4,5,5-decafluoropentanesulfonic acid,  
perfluoropentanesulfonic acid; 2-(perfluorobutyl)ethanesulfonic acid,  
5 1,1,2,2,3,3,4,4,5,5,6,6-dodecafluorohexanesulfonic acid,  
perfluorohexanesulfonic acid, 2-(perfluoropentyl)ethanesulfonic acid,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7-tetradecafluoroheptanesulfonic acid,  
perfluoroheptanesulfonic acid; 2-(perfluorohexyl)ethanesulfonic acid,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8-hexadecafluorooctanesulfonic acid,  
10 perfluorooctanesulfonic acid; 2-(perfluoroheptyl)ethanesulfonic acid,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9-octadecafluorononanesulfonic acid,  
perfluorononanesulfonic acid; 2-(perfluorooctyl)ethanesulfonic acid,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10-eicosafluorodecanesulfonic  
acid, perfluorodecanesulfonic acid; 2-(perfluorononyl)ethanesulfonic  
15 acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11-  
docosafluoroundecanesulfonic acid, perfluoroundecanesulfonic acid;  
2-(perfluorodecyl)ethanesulfonic acid,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12-  
tetracosafuorododecanesulfonic acid, perfluorododecanesulfonic acid;  
20 2-(perfluoroundecyl)ethanesulfonic acid,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13-  
hexacosafuorotridecanesulfonic acid, perfluorotridecanesulfonic acid;  
2-(perfluorododecyl)ethanesulfonic acid,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13,14,14-  
25 octacosafuorotetradecanesulfonic acid, perfluorotetradecanesulfonic  
acid; 2-(perfluorotridecyl)ethanesulfonic acid,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13,14,14,15,1

5-triacontafluoropentadecanesulfonic acid,  
perfluoropentadecanesulfonic acid and the like.

Examples of fluoroalkylcarboxylic acid are

- 2-(perfluoropropyl)ethanecarboxylic acid,  
5 1,1,2,2,3,3,4,4,5,5-decafluoropentane-carboxylic acid,  
perfluoropentane-carboxylic acid; 2-(perfluorobutyl)ethane-carboxylic  
acid, 1,1,2,2,3,3,4,4,5,5,6,6-dodecafluorohexane-carboxylic acid,  
perfluorohexane-carboxylic acid; 2-(perfluoropentyl)ethane-carboxylic  
acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7-tetradecafluoroheptane-carboxylic acid,  
10 perfluoroheptane-carboxylic acid; 2-(perfluorohexyl)ethane-carboxylic  
acid, 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8-hexadecafluorooctane-carboxylic  
acid, perfluorooctane-carboxylic acid;  
2-(perfluoroheptyl)ethane-carboxylic acid,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9-octadecafluorononane-carboxylic  
15 acid, perfluorononane-carboxylic acid;  
2-(perfluorooctyl)ethane-carboxylic acid,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10-eicosafluorodecane-carboxylic  
acid, perfluorodecane-carboxylic acid;  
2-(perfluorononyl)ethane-carboxylic acid,  
20 1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11-  
docosafluoroundecane-carboxylic acid, perfluoroundecane-carboxylic  
acid; 2-(perfluorodecyl)ethane-carboxylic acid,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12-  
tetracosafuorododecane-carboxylic acid, perfluorododecane-carboxylic  
25 acid; 2-(perfluoroundecyl)ethane-carboxylic acid,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13-  
hexacosafuorotridecane-carboxylic acid, perfluorotridecane-carboxylic

acid; 2-(perfluorododecyl)ethanecarboxylic acid,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13,14,14-  
octacosafuorotetradecanecarboxylic acid,  
perfluorotetradecanecarboxylic acid;  
5 2-(perfluorotridecyl)ethanecarboxylic acid,  
1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,11,11,12,12,13,13,14,14,15,1  
5-triacontafuoropentadecanecarboxylic acid,  
perfluoropentadecanecarboxylic acid and the like.

Those fluoroalkylsulfonic acids and fluoroalkylcarboxylic  
10 acids can be used alone or in a mixture of two or more thereof.

Preferred examples of the inorganic acid are sulfuric acid,  
hydrochloric acid, nitric acid, phosphoric acid, hydrofluoric acid,  
hydrobromic acid and the like. Those inorganic acids are preferred for  
the purpose of adjusting a pH value of the coating composition to not  
15 more than 4.0. The inorganic acid is usually used in an amount of  
from 0.01 to 0.2 % by mass based on the coating composition. The  
above-mentioned organic acids and inorganic acids may be used alone  
or in a mixture of two or more thereof.

To the coating composition of the present invention may be  
20 added, as case demands, a water soluble polymer other than the  
fluorine-containing polymer (A1). The water soluble polymer can be  
used for improving film forming property, and may be used within a  
range (kind and amount of the polymer) neither having an adverse  
effect on a refractive index of the coating film nor lowering  
25 transparency of the coating film.

Examples of the water soluble polymer are, for instance,  
polyvinyl alcohols, polyalkyl vinyl ethers (polymethyl vinyl ether,

polyethyl vinyl ether), polyacrylic acids, acrylate resins having carboxyl group, polymethacrylates, polyethylene glycols, celluloses and the like.

A composition obtained by blending the water soluble polymer to the coating composition of the present invention is useful  
5 as a reflection reducing composition used for KrF resist and the like, and can make it possible to reduce an amount of perfluoroalkyl sulfonic acids (for example, those having 4 to 8 carbon atoms) which have been used for conventional compositions or can make use thereof unnecessary.

10 An amount of the water soluble polymer is from 0.1 to 100 parts by mass, preferably from 0.5 to 50 parts by mass, more preferably from 1 to 30 parts by mass, particularly preferably from 1 to 10 parts by mass based on 100 parts by mass of the fluorine-containing polymer (A1) contained in the coating composition.

15 To the coating composition of the present invention may be added, as case demands, a known photoacid generator. The addition of a photoacid generator to the coating composition can prevent diffusion and migration of an acid to the antireflection layer from the photoresist layer after the exposure and the resist pattern profile can  
20 be prevented from being in the form of T-top.

Examples of the acid generator are, for instance, onium salt, haloalkyl group-containing compound, o-quinonediazide compound, nitrobenzyl compound, sulfonic acid ester compound, sulfone compound and the like. Those acid generators can be used alone or  
25 in a mixture of two or more thereof. The preferred acid generator is onium salt.

An amount of the acid generator is usually not more than

20 parts by mass, preferably not more than 10 parts by mass, particularly preferably not more than 5 parts by mass based on 100 parts by mass of the fluorine-containing polymer (A1) contained in the coating composition. If the amount of the acid generator is too large,  
5 there is a tendency that developing property of the laminated resist is lowered and transparency and a refractive index of the antireflection film are deteriorated.

Also to the coating composition forming the antireflection film of the present invention may be added, as case demands, a  
10 defoaming agent, light absorbing agent, storage stabilizer, antiseptic agent, adhesion promoter, photoacid generator, dye and the like.

In the coating composition of the present invention, the content of the fluorine-containing polymer (A1) having hydrophilic group varies depending on kind and molecular weight of the polymer,  
15 kind and amount of additives, kind of a solvent and the like, and is optionally selected so that a suitable viscosity being capable of forming a thin coating film is obtained. For example, the content is from 0.1 to 50 % by mass, preferably from 0.5 to 30 % by mass, more preferably from 1 to 20 % by mass, particularly preferably from 2 to 10 % by  
20 mass based on the whole coating composition.

In the claims and specification of the present invention, physical properties are measured by the following methods. Measuring methods of a pKa value, refractive index, dissolution rate in a developing solution and reflectance are explained in examples.  
25 (1) Analysis of composition: Calculated from data of  $^1\text{H}$ -NMR,  $^{19}\text{F}$ -NMR and IR.

AC-300 available from BRUKER is used for NMR.

Measurement is carried out at room temperature under the following conditions:

Measuring conditions of  $^1\text{H}$ -NMR: 300 MHz

(Tetramethylsilane=0 ppm)

5 Measuring conditions of  $^{19}\text{F}$ -NMR: 282 MHz

(Trichlorofluoromethane=0 ppm)

IR analysis: Measurement is carried out at room temperature with a Fourier-transform infrared spectrophotometer 1760X available from Perkin Elmer Co., Ltd.

10 (2) Fluorine content (% by mass):

The fluorine content is obtained by burning 10 mg of a sample by an oxygen flask combustion method, absorbing cracked gas in 20 ml of de-ionized water and then measuring a fluorine ion concentration in the solution by a fluoride-ion selective electrode method (using a fluorine ion meter model 901 available from Orion).

(3) Number average molecular weight:

A number average molecular weight is calculated based on monodisperse polystyrene from the data measured with gel permeation chromatography (GPC) by using GPC HLC-8020 available from Toso Kabushiki Kaisha and columns available from Shodex (one GPC KF-801, one GPC KF-802 and two GPC KF-806M were connected in series) and flowing tetrahydrofuran (THF) as a solvent at a flowing rate of 1 ml/min.

20 (4) Content of hydrophilic groups Y (number of moles/100 g of polymer):

Calculated from data of  $^1\text{H}$ -NMR,  $^{19}\text{F}$ -NMR and IR. AC-300 available from BRUKER is used for NMR.

Measurement is carried out at room temperature under the following conditions:

Measuring conditions of  $^1\text{H}$ -NMR: 300 MHz

(Tetramethylsilane=0 ppm)

5 Measuring conditions of  $^{19}\text{F}$ -NMR: 282 MHz

(Trichlorofluoromethane=0 ppm)

and the number of moles of hydrophilic groups contained in 100 g of polymer is calculated from the proportions of each structural unit in the polymer.

10 (5) Measurement of pH value of coating composition

Measurement of a pH value is carried out at 25°C with a pH METER F-22 available from HORIBA.

The present invention is then explained by means of examples but is not limited to them.

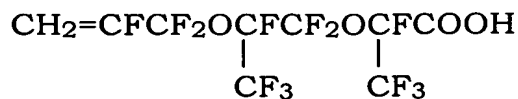
15

#### PREPARATION EXAMPLE 1

(Synthesis of fluorine-containing polymer having -COOH as the hydrophilic group Y)

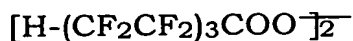
20 Into a 100 ml four-necked glass flask equipped with a stirrer and thermometer were poured 21.1 g of perfluoro-(9,9-dihydro-2,5-bistrifluoromethyl-3,6-dioxa-8-nonenoic acid):

25



and 21.6 g of perfluorohexane solution of 8.0 % by mass of:





and after sufficiently replacing the inside of the flask with nitrogen gas, polymerization reaction was continued at 20°C for 24 hours in nitrogen  
5 gas atmosphere and a solid having a high viscosity was obtained.

The obtained solid dissolved in acetone was poured into n-hexane and was subjected to separation and vacuum drying to obtain 17.6 g of a colorless transparent polymer.

According to <sup>1</sup>H-NMR, <sup>19</sup>F-NMR and IR analyses, the  
10 obtained polymer was found to be a fluorine-containing polymer containing only a structural unit of the above-mentioned fluorine-containing allyl ether having COOH group.

With respect to the molecular weight of the polymer, the above-mentioned GPC measurement was carried out after  
15 methyl-esterification of the carboxyl group in the polymer by the following method.

(Reaction of methyl-esterification)

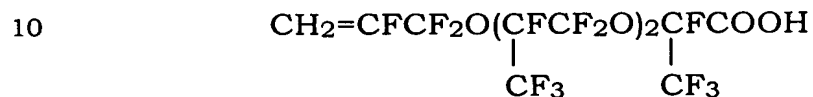
In 5 ml of tetrahydrofuran (THF) was dissolved 1 g of the obtained polymer, and titration of 2-N hexane solution of  
20 trimethylsilyldiazomethane was carried out with stirring until the reaction solution turned to light yellow. After the reaction, the solvent was distilled off under reduced pressure and according to <sup>1</sup>H-NMR analysis of the obtained reaction product, it was confirmed that all COOH groups of the sample was converted to methyl ester.

25 After the conversion to methyl ester, the number average molecular weight of the fluorine-containing polymer measured by GPC was 13,000.

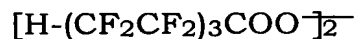
## PREPARATION EXAMPLE 2

(Synthesis of fluorine-containing polymer having COOH group as the hydrophilic group Y)

Polymerization reaction and separation of a polymer were  
5 carried out in the same manner as in Preparation Example 1 except  
that 23.5 g of  
perfluoro-(12,12-dihydro-2,5,8-tristrifluoromethyl-3,6,9-trioxa-11-  
dodecenoic acid):



was used instead of  
perfluoro-(9,9-dihydro-2,5-bistrifluoromethyl-3,6-dioxa-8-nonenoic  
15 acid) and 17.3 g of perfluorohexane solution of 8.0 % by mass of:



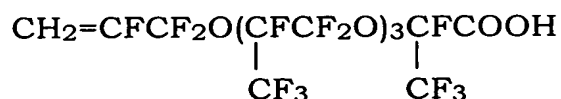
was used, and 20.6 g of a colorless transparent polymer was obtained.

20 According to  $^1\text{H}$ -NMR,  $^{19}\text{F}$ -NMR and IR analyses, the  
obtained polymer was found to be a fluorine-containing polymer  
containing only a structural unit of the above-mentioned  
fluorine-containing allyl ether having COOH group.

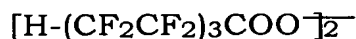
## 25 PREPARATION EXAMPLE 3

(Synthesis of fluorine-containing polymer having COOH group as the hydrophilic group Y)

Polymerization reaction and separation of a polymer were carried out in the same manner as in Preparation Example 1 except that 22.6 g of perfluoro-(15,15-dihydro-2,5,8,11-tetrakis(trifluoromethyl)-3,6,9,12-tetraoxa-14-pentadecenic acid):



was used instead of perfluoro-(9,9-dihydro-2,5-bis(trifluoromethyl)-3,6-dioxo-8-nonenoic acid) and 12.9 g of perfluorohexane solution of 8.0 % by mass of:



was used, and 18.6 g of a colorless transparent polymer was obtained.

According to  $^1\text{H}$ -NMR,  $^{19}\text{F}$ -NMR and IR analyses, the obtained polymer was found to be a fluorine-containing polymer containing only a structural unit of the above-mentioned fluorine-containing allyl ether having COOH group.

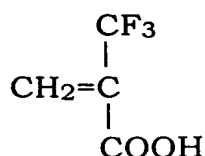
#### PREPARATION EXAMPLE 4

(Synthesis of fluorine-containing polymer having COOH group as the hydrophilic group Y)

Into a 100 ml four-necked glass flask equipped with a stirrer and thermometer were poured 5.0 g of 1,1,2,4,4,8-hexahydro-3-oxa-1-octene:  $\text{CH}_2=\text{CHOCH}_2(\text{CF}_2\text{CF}_2)_2\text{H}$ , 50 g

of ethyl acetate and 0.03 g of azobisisobutyronitrile (AIBN), and after replacing the inside of the system with nitrogen gas, 5 g of 2-(trifluoromethyl)acrylic acid:

5



was added and a reaction was continued at 60°C in a stream of  
10 nitrogen gas with stirring.

The obtained reaction solution was taken out and was subjected to re-precipitation with a hexane solvent to separate a solid. This solid was subjected to vacuum drying until a constant weight was reached, and 9.1 g of a copolymer in the form of white powder was  
15 obtained.

According to <sup>1</sup>H-NMR and <sup>19</sup>F-NMR analyses, the copolymer was one containing perfluoro(1,1,2,4,4,8-hexahydro-3-oxa-1-octene) and 2-(trifluoromethyl)acrylic acid in a percent by mole ratio of 50/50. The number average molecular weight thereof was 87,000.

20

#### PREPARATION EXAMPLE 5

(Synthesis of fluorine-containing polymer having COOH group as the hydrophilic group Y)

Polymerization reaction and separation of a polymer were  
25 carried out in the same manner as in Preparation Example 4 except that 4.0 g of maleic anhydride was used instead of 2-(trifluoromethyl)acrylic acid, and 8.2 g of a polymer in the form of

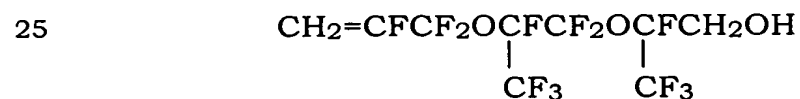
According to  $^1\text{H}$ -NMR and  $^{19}\text{F}$ -NMR analyses, the copolymer was one containing perfluoro(1,1,2,4,4,8-hexahydro-3-oxa-1-octene) and maleic anhydride in a percent by mole ratio of 50/50.

5           The obtained polymer was poured into 100 ml of aqueous  
solution of 1N-NaOH and was dissolved homogeneously by stirring.  
To this solution was added 35 % concentrated hydrochloric acid to  
adjust its pH value to 2 or less. The acidic solution was extracted  
with dichloromethane to take out an organic substance. After drying  
10 of the organic layer, dichloromethane was concentrated and distilled  
off. As a result, 7.0 g of a copolymer in the form of white solid was  
obtained.

According to  $^1\text{H}$ -NMR and  $^{19}\text{F}$ -NMR analyses, the copolymer was one containing perfluoro(1,1,2,4,4,8-hexahydro-3-oxa-1-octene) and maleic acid in a percent by mole ratio of 50/50.

(Synthesis of fluorine-containing polymer having OH group as the hydrophilic group Y)

20 Polymerization reaction and separation of a polymer were carried out in the same manner as in Preparation Example 1 except that 20.4 g of (1,1,9,9-tetrahydro-2,5-bistrifluoromethyl-3,6-dioxo-8-nonenol):



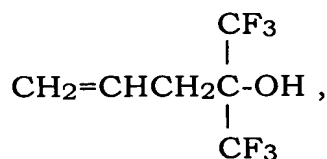
was used instead of perfluoro-(9,9-dihydro-2,5-bistrifluoromethyl-3,6-dioxa-8-nonenoic acid) and 17.1 g of a colorless transparent polymer was obtained.

According to  $^1\text{H}$ -NMR,  $^{19}\text{F}$ -NMR and IR analyses, the obtained polymer was found to be a fluorine-containing polymer containing only a structural unit of the above-mentioned fluorine-containing allyl ether having OH group.

#### PREPARATION EXAMPLE 7

(Synthesis of fluorine-containing polymer having OH group as the hydrophilic group Y)

Into a 100 ml stainless steel autoclave equipped with a valve, pressure gauge and thermometer were poured 5.2 g of 1,1-bistrifluoromethyl-3-buten-1-ol:



30 ml of  $\text{CH}_3\text{CCl}_2\text{F}$  (HCFC-141b) and 10 g of perfluorohexane solution of 10 % by mole of n-heptafluorobutyryl peroxide (HBP), and the inside of the system was sufficiently replaced with nitrogen gas while cooling with dry ice/methanol solution. Then 10 g of tetrafluoroethylene (TFE) was introduced through the valve and a reaction was carried out at  $30^\circ\text{C}$  with shaking. During the reaction, there was no change in a gauge pressure in the system (9.0 MPaG before starting of the reaction), and also 20 hours after, the gauge pressure was 9.0 MPaG.

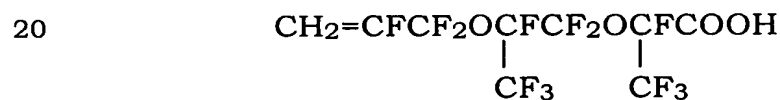
Twenty hours after starting of the reaction, the unreacted monomer was released. The precipitated solid was taken out and dissolved in acetone and was subjected to re-precipitation with a hexane solvent to separate and refine a solid. The solid was vacuum-dried until a constant weight was reached, and 3.0 g of a copolymer was obtained.

According to  $^1\text{H}$ -NMR and  $^{19}\text{F}$ -NMR analyses, the copolymer was one containing 1,1-bistrifluoromethyl-3-buten-1-ol and tetrafluoroethylene in a percent by mole ratio of 50/50. The number average molecular weight thereof was 4,900.

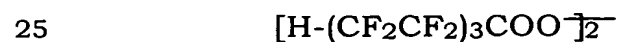
#### PREPARATION EXAMPLE 8

(Synthesis of fluorine-containing polymer having -COOH group as the hydrophilic group Y)

Polymerization reaction and post-treatment were carried out in the same manner as in Preparation Example 1 except that 40.0 g of perfluoro-(9,9-dihydro-2,5-bistrifluoromethyl-3,6-dioxa-8-nonenoic acid):



and 59.2 g of perfluorohexane solution of 8.0 % by mass of:



were used, and 38.2 g of a colorless transparent polymer was obtained.

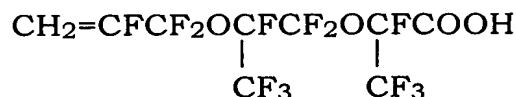
According to  $^1\text{H}$ -NMR,  $^{19}\text{F}$ -NMR and IR analyses, the obtained polymer was found to be a fluorine-containing polymer containing only a structural unit of the above-mentioned fluorine-containing allyl ether having COOH group.

Also GPC measurement was carried out after methyl-esterification of carboxyl group in the same manner as in Preparation Example 1. The number average molecular weight thereof was 7,800.

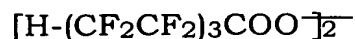
# PREPARATION EXAMPLE 9

(Synthesis of fluorine-containing polymer having -COOH group as the hydrophilic group Y)

Polymerization reaction and post-treatment were carried out in the same manner as in Preparation Example 1 except that 40.0 g of perfluoro-(9,9-dihydro-2,5-bistrifluoromethyl-3,6-dioxo-8-nonenic acid):



and 8.46 g of perfluorohexane solution of 8.0 % by mass of:



were used, and 32.6 g of a colorless transparent polymer was obtained.

According to  $^1\text{H}$ -NMR,  $^{19}\text{F}$ -NMR and IR analyses, the obtained polymer was found to be a fluorine-containing polymer



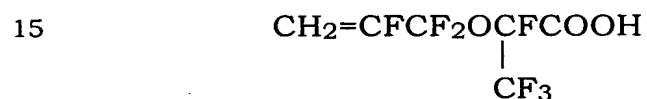
containing only a structural unit of the above-mentioned fluorine-containing allyl ether having COOH group.

Also GPC measurement was carried out after methyl-esterification of carboxyl group in the same manner as in Preparation Example 1. The number average molecular weight thereof was 29,000.

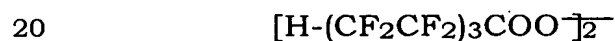
#### PREPARATION EXAMPLE 10

(Synthesis of fluorine-containing polymer having -COOH group as the hydrophilic group Y)

Into a 100 ml four-necked glass flask equipped with a stirrer and thermometer were poured 30.0 g of perfluoro-(6,6-dihydro-2-trifluoromethyl-3-oxa-5-hexenoic acid):



and 31.4 g of perfluorohexane solution of 8.0 % by mass of:



and after sufficiently replacing the inside of the flask with nitrogen gas, polymerization reaction was continued at 20°C for 24 hours in nitrogen gas atmosphere and a solid having a high viscosity was obtained.

The obtained solid dissolved in acetone was poured into n-hexane and then subjected to separation and vacuum drying to obtain 27.9 g of a colorless transparent polymer.

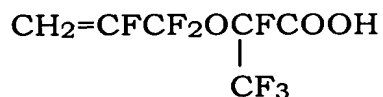
According to  $^1\text{H}$ -NMR,  $^{19}\text{F}$ -NMR and IR analyses, the obtained polymer was found to be a fluorine-containing polymer containing only a structural unit of the above-mentioned fluorine-containing allyl ether having COOH group.

5           Also GPC measurement was carried out after methyl-esterification of carboxyl group in the same manner as in Preparation Example 1. The number average molecular weight thereof was 11,000.

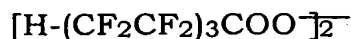
10                                   PREPARATION EXAMPLE 11

(Synthesis of fluorine-containing polymer having -COOH group as the hydrophilic group Y)

Polymerization reaction and post-treatment were carried out in the same manner as in Preparation Example 10 except that 50.0 g of  
15   perfluoro-(6,6-dihydro-2-trifluoromethyl-3-oxa-5-hexenoic acid):



20   and 13.9 g of perfluorohexane solution of 8.0 % by mass of:



were used, and 43.2 g of a colorless transparent polymer was obtained.

25           According to  $^1\text{H}$ -NMR,  $^{19}\text{F}$ -NMR and IR analyses, the obtained polymer was found to be a fluorine-containing polymer containing only a structural unit of the above-mentioned

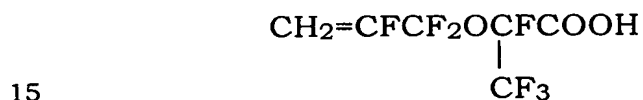
fluorine-containing allyl ether having COOH group.

Also GPC measurement was carried out after methyl-esterification of carboxyl group in the same manner as in Preparation Example 1. The number average molecular weight thereof  
5 was 34,000.

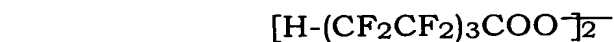
#### PREPARATION EXAMPLE 12

(Synthesis of fluorine-containing polymer having -COOH group as the hydrophilic group Y)

10 Polymerization reaction and post-treatment were carried out in the same manner as in Preparation Example 10 except that 5.0 g of perfluoro-(6,6-dihydro-2-trifluoromethyl-3-oxa-5-hexenoic acid):



and 1.39 g of perfluorohexane solution of 8.0 % by mass of:



were used, and 4.1 g of a colorless transparent polymer was obtained.

According to  $^1\text{H}$ -NMR,  $^{19}\text{F}$ -NMR and IR analyses, the obtained polymer was found to be a fluorine-containing polymer containing only a structural unit of the above-mentioned  
25 fluorine-containing allyl ether having COOH group.

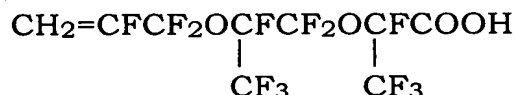
Also GPC measurement was carried out after methyl-esterification of carboxyl group in the same manner as in

Preparation Example 1. The number average molecular weight thereof was 55,000.

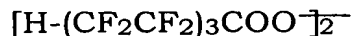
### PREPARATION EXAMPLE 13

5 (Synthesis of fluorine-containing polymer having -COOH group as the hydrophilic group Y)

Polymerization reaction and post-treatment were carried out in the same manner as in Preparation Example 10 except that 50.0 g of perfluoro-(9,9-dihydro-2,5-bistrifluoromethyl-3,6-dioxo-8-nonen-10-  
10 acid):



15 and 5.3 g of perfluorohexane solution of 8.0 % by mass of:



were used, and 39.5 g of a colorless transparent polymer was obtained.

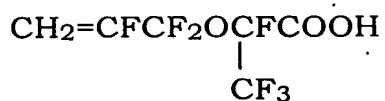
20 According to  $^1\text{H}$ -NMR,  $^{19}\text{F}$ -NMR and IR analyses, the obtained polymer was found to be a fluorine-containing polymer containing only a structural unit of the above-mentioned fluorine-containing allyl ether having COOH group.

Also GPC measurement was carried out after  
25 methyl-esterification of carboxyl group in the same manner as in Preparation Example 1. The number average molecular weight thereof was 50,000.

#### PREPARATION EXAMPLE 14

(Synthesis of fluorine-containing polymer having -COOH group as the hydrophilic group Y)

Into a 100 ml four-necked glass flask equipped with a stirrer and thermometer were poured 10.0 g of perfluoro-(6,6-dihydro-2-trifluoromethyl-3-oxa-5-hexenoic acid):



10

and a solution prepared by dissolving 89 mg of ammonium persulfate in 20 g of water and after sufficiently replacing the inside of the flask with nitrogen gas, polymerization reaction was continued at 80°C for six hours in nitrogen gas atmosphere. After completion of the polymerization, to the obtained solution was added 10 g of 10 % hydrochloric acid to precipitate the polymer. The precipitated polymer dissolved in acetone was poured into n-hexane and then subjected to separation and vacuum drying to obtain 8.3 g of a colorless transparent polymer.

20

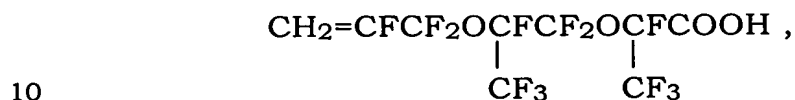
According to  $^1\text{H}$ -NMR,  $^{19}\text{F}$ -NMR and IR analyses, the obtained polymer was found to be a fluorine-containing polymer containing only a structural unit of the above-mentioned fluorine-containing allyl ether having COOH group.

Also GPC measurement was carried out after methyl-esterification of carboxyl group in the same manner as in Preparation Example 1. The number average molecular weight thereof was 54,000.

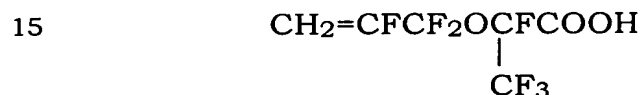
### PREPARATION EXAMPLE 15

(Synthesis of fluorine-containing polymer having -COOH group as the hydrophilic group Y)

Into a 100 ml four-necked glass flask equipped with a  
5 stirrer and thermometer were poured 25.0 g of  
perfluoro-(9,9-dihydro-2,5-bistrifluoromethyl-3,6-dioxa-8-nonenoic  
acid):



25.0 g of perfluoro-(6,6-dihydro-2-trifluoromethyl-3-oxa-5-hexenoic  
acid):



and a solution prepared by dissolving 180 mg of ammonium persulfate  
in 100 g of water and after sufficiently replacing the inside of the flask  
20 with nitrogen gas, polymerization reaction was continued at 80°C for  
six hours in nitrogen gas atmosphere. After completion of the  
polymerization, to the obtained solution was added 50 g of 10 %  
hydrochloric acid to precipitate the polymer. The precipitated polymer  
dissolved in acetone was poured into n-hexane and then subjected to  
25 separation and vacuum drying to obtain 38 g of a colorless transparent  
polymer.

According to  $^1\text{H}$ -NMR,  $^{19}\text{F}$ -NMR and IR analyses, the

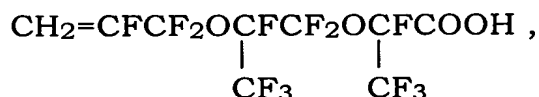
obtained polymer was found to be a fluorine-containing polymer containing perfluoro-(9,9-dihydro-2,5-bistrifluoromethyl-3,6-dioxo-8-nonenoic acid) and perfluoro-(6,6-dihydro-2-trifluoromethyl-3-oxa-5-hexenoic acid) in a percent by mole ratio of 38/62.

Also GPC measurement was carried out after methyl-esterification of carboxyl group in the same manner as in Preparation Example 1. The number average molecular weight thereof was 39,000.

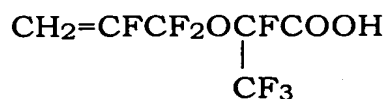
# PREPARATION EXAMPLE 16

(Synthesis of fluorine-containing polymer having -COOH group as the hydrophilic group Y)

Into a 100 ml four-necked glass flask equipped with a stirrer and thermometer were poured 15.0 g of perfluoro-(9,9-dihydro-2,5-bistrifluoromethyl-3,6-dioxo-8-nonenoic acid):



35.0 g of perfluoro-(6,6-dihydro-2-trifluoromethyl-3-oxa-5-hexenoic acid):



and a solution prepared by dissolving 200 mg of ammonium persulfate

in 100 g of water and after sufficiently replacing the inside of the flask with nitrogen gas, polymerization reaction was continued at 80°C for six hours in nitrogen gas atmosphere. After completion of the polymerization, to the obtained solution was added 50 g of 10 %  
5 hydrochloric acid to precipitate the polymer. The precipitated polymer dissolved in acetone was poured into n-hexane and then subjected to separation and vacuum drying to obtain 8.3 g of a colorless transparent polymer.

The obtained solid was dissolved in acetone, poured into  
10 n-hexane and then subjected to separation and vacuum drying to obtain 39 g of a colorless transparent polymer.

According to <sup>1</sup>H-NMR, <sup>19</sup>F-NMR and IR analyses, the obtained polymer was found to be a fluorine-containing polymer containing perfluoro-(9,9-dihydro-2,5-bistrifluoromethyl-3,6-dioxa-8-  
15 nonenoic acid) and perfluoro-(6,6-dihydro-2-trifluoromethyl-3-oxa-5-hexenoic acid) in a percent by mole ratio of 17/83.

Also GPC measurement was carried out after methyl-esterification of carboxyl group in the same manner as in Preparation Example 1. The number average molecular weight thereof  
20 was 37,000.

#### EXPERIMENTAL EXAMPLE 1

(To confirm solubility of fluorine-containing polymer in a solvent)

Solubility in water and alcohols was confirmed using the  
25 fluorine-containing polymers having hydrophilic group which were obtained in Preparation Examples 1 to 7 and 10 to 18.

The polymers were blended in each solvent shown in Table



1 so that concentrations thereof became 5 % by mass, and were allowed to stand at room temperature for 24 hours with stirring. Then appearance of the solutions was evaluated. The evaluation was made by the following criteria. The results are shown in Table 1.

5 ○ : A polymer is completely soluble, and a solution becomes transparent and homogeneous.

× : A polymer is partly insoluble or completely insoluble, and a solution is not transparent.

TABLE 1

	Water	Methanol	Ethanol	Isopropanol
Preparation Example 1	○	○	○	○
Preparation Example 2	○	○	○	○
Preparation Example 3	×	×	×	×
Preparation Example 4	○	○	○	○
Preparation Example 5	○	○	○	○
Preparation Example 6	×	○	○	○
Preparation Example 7	×	○	○	○
Preparation Example 10	○	○	○	○
Preparation Example 11	○	○	○	○
Preparation Example 12	○	○	○	○
Preparation Example 13	○	○	○	○
Preparation Example 14	○	○	○	○
Preparation Example 15	○	○	○	○
Preparation Example 16	○	○	○	○
Preparation Example 17	○	○	○	○
Preparation Example 18	○	○	○	○

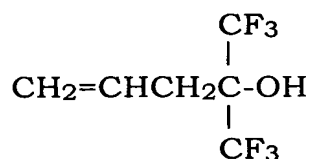
## EXPERIMENTAL EXAMPLE 2

(Measurement of a pKa value of a monomer having hydrophilic group)

With respect to the monomers having hydrophilic group used in Preparation Examples 1 to 7 and 10, a pKa value of hydrophilic group thereof was calculated by the following method (in Preparation Example 5, measurement was made with respect to maleic acid instead of maleic anhydride).

(Method of determining a pKa value)

The method of determining a pKa value is mentioned below using 1,1-bistrifluoromethyl-3-buten-1-ol:



15

(used in Preparation Example 7) as an example of a monomer.

In a water/acetone mixture (10/15 ml) solution was poured 0.7865 g of  $\text{CH}_2=\text{CHCH}_2\text{C}(\text{CF}_3)_2\text{OH}$ , followed by stirring at room temperature. After it was confirmed that the solution was homogeneous, titration was carried out with about 0.2 mol/L NaOH solution. A titration curve was obtained by adding the NaOH solution dropwise in increments of 0.15 ml and recording a pH value at every addition. An equivalence point was determined by an inflection point (maximum differential value of titration curve =  $\text{dpH/dml}$ ) of the titration curve. In this case, the equivalence point was 14.5 ml. A pH value at 7.25 ml which was a half of the equivalence point was read from the titration curve and was found to be 10.58. From a titration

curve of water/acetone solution and aqueous solution which had been measured previously as a blank solution, a difference in a pH value derived from an electric potential difference between the solutions at titration of 7.25 ml was 1.29. Therefore from  $10.98 - 1.29 = 9.69$ , it was decided that a pKa value of this  $\text{CH}_2=\text{CHCH}_2\text{C}(\text{CF}_3)_2\text{OH}$  was 9.69.

In the case of titration of 1.0865 g of  $\text{CH}_2=\text{CHCH}_2\text{C}(\text{CF}_3)_2\text{OH}$  by the same procedures as above, an equivalence point was 20.15 ml and a half of equivalence point was 10.08 ml. A pH value at a half of the equivalence point was 10.78. A difference in a pH value between the both solutions at 10.08 ml was 1.14, and from  $10.78 - 1.14 = 9.64$ , it was decided that a pKa value of  $\text{CH}_2=\text{CHCH}_2\text{C}(\text{CF}_3)_2\text{OH}$  was 9.64.

When the same procedures as above were carried out by changing the titration solution to about 0.05 mol/L NaOH, an equivalence point of 0.115 g of  $\text{CH}_2=\text{CHCH}_2\text{C}(\text{CF}_3)_2\text{OH}$  was 8.00 ml and a half of the equivalence point was 4.00 ml. A pH value at this time was 10.92. A difference in a pH value between the both solutions at 4.00 ml was 1.38, and from  $10.92 - 1.38 = 9.54$ , it was decided that a pKa value of  $\text{CH}_2=\text{CHCH}_2\text{C}(\text{CF}_3)_2\text{OH}$  was 9.54.

From those experiments carried out three times, it was decided that a pKa value of  $\text{CH}_2=\text{CHCH}_2\text{C}(\text{CF}_3)_2\text{OH}$  was 9.6.

With respect to the various fluorine-containing ethylenic monomers having OH group shown in Table 2, a pKa value was measured by the same procedures as above. The results are shown in Table 2.

TABLE 2

	Monomer having hydrophilic group	pKa
Prep. Ex. 1	$\begin{array}{c} \text{CH}_2=\text{CFCF}_2\text{OCFCF}_2\text{OCFCOOH} \\   \quad \quad   \\ \text{CF}_3 \quad \quad \text{CF}_3 \end{array}$	3.6
Prep. Ex. 2	$\begin{array}{c} \text{CH}_2=\text{CFCF}_2\text{O}(\text{CFCF}_2\text{O})_2\text{CFCOOH} \\   \quad \quad   \\ \text{CF}_3 \quad \quad \text{CF}_3 \end{array}$	3.8
Prep. Ex. 3	$\begin{array}{c} \text{CH}_2=\text{CFCF}_2\text{O}(\text{CFCF}_2\text{O})_3\text{CFCOOH} \\   \quad \quad   \\ \text{CF}_3 \quad \quad \text{CF}_3 \end{array}$	4.0
Prep. Ex. 4	$\begin{array}{c} \text{CH}_2=\text{C}(\text{CF}_3) \\   \\ \text{COOH} \end{array}$	3.9
Prep. Ex. 5	Maleic acid	1.4
Prep. Ex. 6	$\begin{array}{c} \text{CH}_2=\text{CFCF}_2\text{OCFCF}_2\text{OCFCH}_2\text{OH} \\   \quad \quad   \\ \text{CF}_3 \quad \quad \text{CF}_3 \end{array}$	12.6
Prep. Ex. 7	$\begin{array}{c} \text{CF}_3 \\   \\ \text{CH}_2=\text{CHCH}_2\text{C}-\text{OH} \\   \\ \text{CF}_3 \end{array}$	9.6
Prep. Ex. 10	$\begin{array}{c} \text{CH}_2=\text{CFCF}_2\text{OCFCOOH} \\   \\ \text{CF}_3 \end{array}$	3.4

### EXPERIMENTAL EXAMPLE 3

(Measurement of fluorine content and hydrophilic group content)

- 5            With respect to the fluorine-containing polymers having hydrophilic group obtained in Preparation Examples 1 to 7, 10 and 15 to 18, a fluorine content (% by mass) and a hydrophilic group content (number of moles/100 g of polymer) thereof were measured. The results are shown in Table 3.

TABLE 3

	Fluorine content (% by mass)	Hydrophilic group content (number of moles/100 g of polymer)
Prep. Ex. 1	58.5	0.237
Prep. Ex. 2	61.4	0.170
Prep. Ex. 3	64.2	0.135
Prep. Ex. 4	52.5	0.251
Prep. Ex. 5	42.4	0.532
Prep. Ex. 6	60.5	0.245
Prep. Ex. 7	61.6	0.324
Prep. Ex. 10	52.0	0.39
Prep. Ex. 15	54.9	0.323
Prep. Ex. 16	53.6	0.352
Prep. Ex. 17	55.8	0.33
Prep. Ex. 18	54.0	0.36

#### EXPERIMENTAL EXAMPLE 4

(Preparation of coating composition)

- 5           The fluorine-containing polymers obtained in Preparation Examples 1, 2, 4 and 5 respectively were dissolved in an amount of 10 g in 10 ml of methanol. The obtained total amount of methanol solution of fluorine-containing polymer was added dropwise in 150 ml of pure water over about ten minutes at room temperature with stirring.
- 10   Further pure water was added thereto to adjust the total amount of composition to 200 ml, followed by filtrating with a filter having an opening size of 0.2  $\mu\text{m}$  to obtain a homogeneous coating composition.

#### EXPERIMENTAL EXAMPLE 5

- 15   (Preparation of coating composition)

          The fluorine-containing polymers obtained in Preparation Examples 6 and 7 respectively were dissolved in an amount of 10 g in 200 ml of methanol, and then subjected to filtration with a filter having an opening size of 0.2  $\mu\text{m}$  to obtain a homogeneous coating

composition.

#### EXPERIMENTAL EXAMPLE 6

(Preparation of coating composition)

5           The fluorine-containing polymer obtained in Preparation Example 3 was dissolved in an amount of 10 g in 200 ml of acetone, and then subjected to filtration with a filter having an opening size of 0.2  $\mu\text{m}$  to obtain a homogeneous coating composition.

#### EXPERIMENTAL EXAMPLE 7

(Preparation of coating composition)

10           The fluorine-containing polymer obtained in Preparation Example 1 was dissolved in an amount of 21.1 g in 20 ml of methanol, and further 0.6 g of ethanolamine was blended thereto. The obtained  
15 total amount of methanol solution of fluorine-containing polymer was added dropwise in 350 ml of pure water over about ten minutes at room temperature with stirring, and further pure water was added thereto to adjust the total amount of composition to 420 ml, followed by filtrating with a filter having an opening size of 0.2  $\mu\text{m}$  to obtain a  
20 homogeneous coating composition.

#### EXPERIMENTAL EXAMPLE 8

(Preparation of coating composition)

25           A coating composition of fluorine-containing polymer was obtained in the same manner as in Experimental Example 7 except that ethanolamine was added in an amount of 1.5 g.

#### EXPERIMENTAL EXAMPLE 9

(Preparation of coating composition)

A coating composition of fluorine-containing polymer was obtained in the same manner as in Experimental Example 7 except  
5 that ethanolamine was added in an amount of 3.0 g.

#### EXPERIMENTAL EXAMPLE 10

(Measurement of refractive index of coating film)

The respective coating compositions prepared in  
10 Experimental Examples 4 to 9 were coated on a 8-inch silicon wafer substrate with a spin coater at 300 rpm for three seconds and then at 4,000 rpm for twenty seconds while rotating the wafer to form a coating film so that a thickness of the dried coating film became about 100 nm.

15 With respect to the respective coating films formed on the silicon wafer substrate by the above-mentioned method, refractive indices thereof were measured. The results are shown in Table 4.

(Measurement of refractive index)

A refractive index at 193 nm wavelength and a coating  
20 thickness are measured with a spectroscopic ellipsometer (VASE ellipsometer available from J.A. Woollam).

#### EXPERIMENTAL EXAMPLE 11

(Measurement of a dissolution rate of a coating film in a developing  
25 solution)

A dissolution rate (nm/sec) in a developing solution was measured in the manner mentioned below by the quartz crystal



oscillation method (QCM method). The results are shown in Table 4.

Production of sample:

The respective coating compositions prepared in Experimental Examples 4 to 9 were applied on a 24 mm diameter quartz oscillation panel coated with gold and was dried to make an about 100 nm coating film.

Measurement of dissolution rate in a developing solution:

A coating film thickness is calculated by converting the number of oscillations of the quartz crystal oscillation panel.

The quartz oscillation panel produced above by coating the fluorine-containing polymer was dipped in an aqueous solution of 2.38 % by mass of tetramethylammonium hydroxide (TMAH) as a standard developing solution. After the dipping of the panel, a change in a coating thickness was obtained from a change in the number of oscillations with the progress of time, and a dissolution rate per unit time (nm/sec) was calculated (Reference bulletin: Advances in Resist Technology and Proceedings of SPIE Vol. 4690, 904(2002)).

#### EXAMPLE 1

(Formation of laminated resist)

Formation of photoresist layer (L1):

A photoresist TArF-P6071 for ArF lithography (Tokyo Ohka Kogyo Kabushiki Kaisha) was coated on a 8-inch silicon substrate with a spin coater while changing the number of revolutions to adjust the coating thickness to be 200 to 300 nm, followed by pre-baking at 130°C for 60 seconds to form the photoresist layer (L1).

Formation of antireflection layer (L2):

On the photoresist layer (L1) formed above were coated the respective coating compositions containing the fluorine-containing polymer having hydrophilic group which were prepared in Experimental Examples 4, 5 and 7 to 9 with a spin coater at 300 rpm  
5 for three seconds and then at 4,000 rpm for twenty seconds while rotating the wafer to form the antireflection layer (L2) so that the coating thickness became about 100 nm. Thus the laminated photoresist was formed.

The reflectance at 193 nm of the obtained laminated  
10 photoresist was measured. The results are shown in Table 4.  
(Measurement of reflectance)

A reflectance at 193 nm wavelength is measured with a spectroscopic ellipsometer (VASE ellipsometer available from J.A. Woollam).

15 Also with respect to the laminated photoresist produced by forming the antireflection layer (L2) in the same manner as above by using the fluorine-containing polymer which was confirmed to have solubility in a developing solution in Experimental Example 11, stationary puddle-developing was carried out at 23°C for 60 seconds by  
20 using a developing solution of 2.38 % by mass of tetramethylammonium hydroxide and then rinsing with pure water was carried out. It was confirmed that in any of coating compositions, the antireflection layer (L2) had been selectively removed.

TABLE 4

Coating composition	Experimental Example 4						Experimental Example 5
(A) Fluorine-containing polymer	Prep. Ex. 1	Prep. Ex. 2	Prep. Ex. 4	Prep. Ex. 5	Prep. Ex. 6	Prep. Ex. 7	
Fluorine content (% by mass)	58.5	61.4	52.5	42.4	60.5	61.6	
Kind of hydrophilic group	COOH	COOH	COOH	COOH	OH	OH	
pKa value of hydrophilic group	3.6	3.8	3.9	1.4	12.6	9.6	
Hydrophilic group content (mole/100 g of polymer)	0.237	0.170	0.251	0.279	0.245	0.324	
Concentration of polymer (g/100 ml)	5.0	5.0	5.0	5.0	5.0	5.0	
(B) Solvent (% by volume)							
Water	95	95	95	95			
Methanol	5	5	5	5	100	100	
Acetone							

- continued -

- continued -

Coating composition	Experimental Example 6	Experimental Example 7	Experimental Example 8	Experimental Example 9
(A) Fluorine-containing polymer	Prep. Ex. 3		Prep. Ex. 1	
Fluorine content (% by mass)	64.2		58.5	
Kind of hydrophilic group	COOH		COOH	
pKa value of hydrophilic group	4.0		3.6	
Hydrophilic group content (mole/100 g of polymer)	0.135		0.237	
Concentration of polymer (g/100 ml)	5.0		5.0	
(B) Solvent (% by volume)				
Water			95	
Methanol			5	
Acetone	100			

- continued -

- continued -

Coating composition	Experimental Example 4			Experimental Example 5		
(C) Organic amine (equivalent/hydrophilic group)						
Ethanolamine						
Characteristics of coating film						
Refractive index ( $\lambda = 193 \text{ nm}$ )	1.41	1.39	1.45	1.51	1.40	1.43
Dissolution rate in a developing solution (nm/sec)	150	100	1000	1000	insoluble	300
Characteristics of laminated resist						
Reflectance (%)	1.17	0.9	1.84	3.07	1.02	1.49

- continued -

- continued -

Coating composition	Experimental Example 6	Experimental Example 7	Experimental Example 8	Experimental Example 9
(C) Organic amine (equivalent/hydrophilic group)				
Ethanolamine		0.2	0.5	1.0
Characteristics of coating film				
Refractive index ( $\lambda = 193 \text{ nm}$ )	1.38	1.41	1.42	1.43
Dissolution rate in a developing solution (nm/sec)	Insoluble	200	300	500
Characteristics of laminated resist				
Reflectance (%)	-	1.17	1.33	1.49

## EXPERIMENTAL EXAMPLE 12

(Solubility of fluorine-containing polymer (A1) in a solvent mixture of water/isopropanol)

To 1 g each of the respective fluorine-containing polymers  
5 obtained in Preparation Examples 1 and 8 to 18 was added 9 g of a  
solvent mixture of water/isopropanol (IPA) having the composition  
shown in Table 5, followed by allowing to stand at room temperature  
for 24 hours with stirring and then further allowing to stand at room  
temperature for 24 hours. Then appearance of the solution was  
10 observed.

Evaluation was carried out by the following criteria. The  
results are shown in Table 5.

○ : A polymer is completely soluble, and a solution becomes  
transparent and homogeneous and has a low viscosity.

15 △: A solution becomes transparent and homogeneous, but is in the  
form of gel having a high viscosity.

×: The polymer is partly insoluble or completely insoluble, and a  
solution is opaque.

The results are shown in Table 5.

TABLE 5

Polymer (A1)	Prep. Ex.	Prep. Ex.	Prep. Ex.	Prep. Ex.	Prep. Ex.	Prep. Ex.	Prep. Ex.
	8	1	9	10	11	12	
Number average molecular weight	7800	13000	29000	11000	34000	55000	
Solubility							
Water/IPA ratio (% by mass)							
0/100	O	O	O	O	O	O	O
60/40	O	O	O	O	O	O	O
65/35	x	O	O	O	O	O	O
70/30	x	x	O	O	O	O	O
75/25	x	x	x	x	O	O	O
80/20	x	x	x	x	x	x	O
85/15	x	x	x	x	x	x	x
100/0	Δ	Δ	Δ	O	O	O	O

- continued -



- continued -

Polymer (A1)	Prep. Ex.	Prep. Ex.	Prep. Ex.	Prep. Ex.	Prep. Ex.	Prep. Ex.	Prep. Ex.
	13	14	15	16	17	18	
Number average molecular weight	50000	54000	39000	37000	61000	46000	
Solubility							
Water/IPA ratio (% by mass)							
0/100	○	○	○	○	○	○	○
60/40	○	○	○	○	○	○	○
65/35	○	○	○	○	○	○	○
70/30	○	○	○	○	○	○	○
75/25	○	○	○	○	○	○	○
80/20	○	○	×	×	×	○	○
85/15	×	×	×	×	×	○	○
100/0	△	○	○	○	○	○	○

## EXAMPLE 2

(Preparation of coating composition)

The fluorine-containing polymer obtained in Preparation Example 1 was dissolved in an amount of 10 g in 35 g of isopropanol. The total amount of the obtained isopropanol solution of fluorine-containing polymer was added dropwise to 65 g of pure water at room temperature over about 10 minutes with stirring. Further a solution mixture of water/isopropanol of 65/35 % by mass was added thereto to adjust the total amount of the composition to 200 g, and then filtration was carried out with a filter having an opening size of 0.2  $\mu\text{m}$  to obtain a homogeneous coating composition.

## EXAMPLE 3

(Preparation of coating composition)

The fluorine-containing polymer obtained in Preparation Example 9 was dissolved in an amount of 10 g in 30 g of isopropanol. The total amount of the obtained isopropanol solution of fluorine-containing polymer was added dropwise to 70 g of pure water at room temperature over about 10 minutes with stirring. Further a solution mixture of water/isopropanol of 70/30 % by mass was added thereto to adjust the total amount of the composition to 200 g, and then filtration was carried out with a filter having an opening size of 0.2  $\mu\text{m}$  to obtain a homogeneous coating composition.

## EXPERIMENTAL EXAMPLE 13

The fluorine-containing polymer obtained in Preparation Example 8 was dissolved in an amount of 10 g in 40 g of isopropanol.

The total amount of the obtained isopropanol solution of fluorine-containing polymer was added dropwise to 60 g of pure water at room temperature over about 10 minutes with stirring. Further a solution mixture of water/isopropanol of 60/40 % by mass was added thereto to adjust the total amount of the composition to 200 g, and then filtration was carried out with a filter having an opening size of 0.2  $\mu\text{m}$  to obtain a homogeneous coating composition.

#### EXAMPLE 4

10 (Preparation of coating composition)

The fluorine-containing polymer obtained in Preparation Example 10 was mixed in an amount of 10 g to 190 g of pure water, and was completely dissolved by stirring at room temperature for 24 hours. The obtained aqueous solution was filtrated with a filter having an opening size of 0.2  $\mu\text{m}$  to obtain a homogeneous coating composition.

#### EXAMPLE 5

(Preparation of coating composition)

20 A coating composition was obtained in the same manner as in Example 4 except that the fluorine-containing polymer obtained in Preparation Example 11 was used instead of the fluorine-containing polymer obtained in Preparation Example 10.

25 EXAMPLE 6

(Preparation of coating composition)

A coating composition was obtained in the same manner as

in Example 4 except that the fluorine-containing polymer obtained in Preparation Example 12 was used instead of the fluorine-containing polymer obtained in Preparation Example 10.

5

#### EXPERIMENTAL EXAMPLE 14

(Measurement of refractive index of coating film)

A refractive index was measured using light of 193 nm wavelength in the same manner as in Experimental Example 10 after forming a coating film on a silicon wafer by using the coating  
10 compositions obtained in Examples 2, 3 and 4 to 6 and Experimental Example 13.

The results are shown in Table 6.

#### EXPERIMENTAL EXAMPLE 15

15 (Measurement of a dissolution rate of a coating film in a developing solution)

Production of a sample and measurement of a dissolution rate (nm/sec) in a developing solution by the quartz crystal oscillation method (QCM method) were carried out in the same manner as in  
20 Experimental Example 11 by using the respective coating compositions obtained in Examples 2, 3 and 4 to 6 and Experimental Example 13.

The results are shown in Table 6.

#### EXPERIMENTAL EXAMPLE 16

25 (Formation of laminated resist and measurement of reflectance)

Formation of photoresist layer:

A photoresist layer was formed by using a resist for ArF

lithography in the same manner as in Example 1.

Formation of antireflection layer:

A laminated photoresist was obtained by forming an antireflection layer on the photoresist layer formed above in the same manner as in Example 1 by using the respective coating compositions  
5 obtained in Examples 2, 3 and 4 to 6 and Experimental Example 13.

The reflectance of the obtained laminated photoresists was measured with light of 193 nm wavelength in the same manner as in Example 1.

10 The results are shown in Table 6.

TABLE 6

Coating composition	Ex. 2	Ex. 3	Exp. Ex. 13	Ex. 4	Ex. 5	Ex. 6
(A1) Fluorine-containing polymer	Prep. Ex. 1	Prep. Ex. 9	Prep. Ex. 8	Prep. Ex. 10	Prep. Ex. 11	Prep. Ex. 12
Number average molecular weight: Mn	13000	29000	7800	11000	34000	55000
Concentration of polymer (% by mass)	5.0	5.0	5.0	5.0	5.0	5.0
(B) Solvent (% by mass)						
Water	65	70	60	100	100	100
Isopropanol	35	30	40	0	0	0
Characteristics of coating film						
Refractive index (193 nm)	1.41	1.41	1.41	1.44	1.44	1.44
Dissolution rate in a developing solution (nm/sec)	150	500	50	500	1000 or more	1000 or more
Characteristics of laminated resist						
Reflectance (%)	1.17	1.17	1.17	1.65	1.65	1.65

## EXAMPLE 7

(Preparation of coating composition)

(Addition of amine (C))

To 10 g of the fluorine-containing polymer obtained in Preparation Example 1 was mixed diethanolamine (1.5 g) in an amount of 0.6 equivalent based on the carboxyl group contained in the fluorine-containing polymer. Further pure water was added thereto to adjust the total amount of the composition to be 200 g, followed by stirring at room temperature for six hours. Then after allowing the solution to stand at room temperature for 24 hours, appearance of the solution was observed.

The evaluation was carried out by the following criteria.

○ : A polymer is completely soluble, and a solution becomes transparent and homogeneous and has a low viscosity.

△ : A solution becomes transparent and homogeneous, but is in the form of gel having a high viscosity.

× : A polymer is partly insoluble or is completely insoluble, and a solution is opaque.

(Addition 1 of acid (D))

To 50 g of the above-mentioned coating composition containing amine was mixed para-toluenesulfonic acid in an amount of 0.2 equivalent based on the carboxyl group contained in the fluorine-containing polymer. After stirring at room temperature for six hours and then allowing to stand at room temperature for 24 hours, appearance of the solution was observed in the same manner as above.

(Addition 2 of acid (D))

To 50 g of the above-mentioned coating composition

containing amine was mixed perfluoro butanoic acid in an amount of 0.2 equivalent based on the carboxyl group contained in the fluorine-containing polymer. After stirring at room temperature for six hours and then allowing to stand at room temperature for 24 hours, appearance of the solution was observed in the same manner as above. (Measurement of a pH value of a coating composition)

A pH value of the above coating composition was measured with the above-mentioned pH meter. Also a pH value of the coating composition obtained in Example 5 was measured.

The results are shown in Table 7.



TABLE 7

Coating composition	Example 7			Example 5	
	Prep. Ex. 1	Prep. Ex. 1	Prep. Ex. 1	Prep. Ex. 1	Prep. Ex. 11
(A1) Fluorine-containing polymer					
Concentration of polymer (% by mass)	5.0	5.0	5.0	5.0	5.0
(B) Water (content (%) in a solvent)					
	100	100	100	100	100
(C) Diethanolamine (equivalent)					
	0.6	0.6	0.6	-	-
(D) Para-toluenesulfonic acid (equivalent)					
	-	0.2	-	-	-
Perfluoro butanoic acid (equivalent)					
	-	-	0.2	-	-
Evaluation of solubility					
	○	○	○	○	○
pH					
	2.37	1.75	1.86	1.70	1.70

# EXAMPLE 8

(Preparation of coating composition)

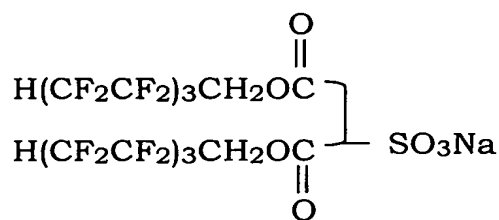
(Addition of surfactant (E))

The fluorine-containing polymer obtained in Preparation  
 5 Example 1 was dissolved in an amount of 10 g in 25 g of isopropanol.  
 The total amount of the obtained isopropanol solution of  
 fluorine-containing polymer was added dropwise to 75 g of pure water  
 at room temperature over about 10 minutes with stirring. Further a  
 solution mixture of water/isopropanol of 75/25 % by mass was added  
 10 thereto to adjust the total amount of the composition to 200 g, and  
 stirring was continued at room temperature for six hours. Then after  
 allowing to stand at room temperature for 24 hours, appearance of the  
 solution was observed. An undissolved substance remains partly in  
 the solution and the solution was opaque.

15 The above composition was separated to four compositions  
 of 50 g each, and to the respective compositions was added 0.05 g  
 (2.0 % by mass based on the polymer in the composition) of a  
 surfactant of the following formulae (E-1), (E-2), (E-3) and (E-4):

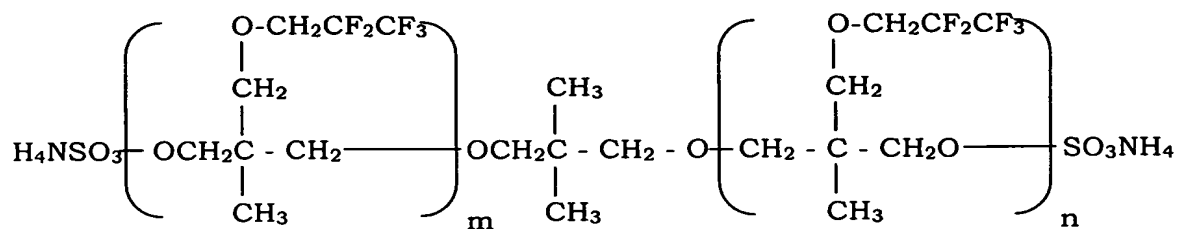
20 (E-1):  $C_7F_{15}COONH_4$

(E-2):



25

(E-3):



5

( $1 \leq m + n \leq 50$ , an average of  $m + n$  is 7)

(E-4): A copolymer which has a number average molecular weight of 12,000 (based on styrene) and is prepared by copolymerizing:

- 20 g of a compound represented by
- 10  $\text{CF}_3\text{CF}_2(\text{CF}_2\text{CF}_2)_n\text{CH}_2\text{CH}_2\text{OCOC}(\text{CH}_3)=\text{CH}_2$  (a mixture of compounds of  $n=3$ ,  $n=4$  and  $n=5$  in a weight ratio of 5:3:1),
- 10 g of  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COO}(\text{CH}_2\text{CH}_2\text{O})_9\text{CH}_3$ ,
- 5 g of  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COO}(\text{CH}_2\text{CH}(\text{CH}_3)\text{O})_{12}\text{H}$ ,
- 4 g of  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COOCH}_2\text{CH}(\text{OH})\text{CH}_2\text{Cl}$  and
- 15 1 g of  $\text{CH}_2=\text{C}(\text{CH}_3)\text{COOCH}_2\text{CH}(\text{OH})\text{CH}_2\text{OH}$ ,

and then stirring was continued at room temperature for six hours. Then after allowing to stand at room temperature for 24 hours, appearance of the solution was observed.

20 The evaluation was carried out by the following criteria.

○ : A polymer is completely soluble, and a solution becomes transparent and homogeneous and has a low viscosity.

△: A solution becomes transparent and homogeneous, but is in the form of gel having a high viscosity.

25 ×: A polymer is partly insoluble or is completely insoluble, and a solution is opaque.

The results are shown in Table 8.

TABLE 8

Coating composition									
(A) Fluorine-containing polymer		Prep. Ex.	Prep. Ex.	Prep. Ex.	Prep. Ex.	Prep. Ex.	Prep. Ex.	Prep. Ex.	Prep. Ex.
		1	1	1	1	1	1	1	1
(B) Solvent (% by mass in a solvent)									
Water/isopropanol		75/25	75/25	75/25	75/25	75/25	75/25	75/25	75/25
(E) Surfactant (% by mass based on polymer)									
(E-1)		-	2.0	-	-	-	-	-	-
(E-2)		-	-	-	2.0	-	-	-	-
(E-3)		-	-	-	-	2.0	-	-	-
(E-4)		-	-	-	-	-	-	-	2.0
Evaluation of solubility									
		×	○	○	○	○	○	○	○

### EXAMPLE 9

(Preparation of coating composition)

The fluorine-containing polymer obtained in Preparation Example 13 was dissolved in an amount of 10 g in 20 g of isopropanol. The total amount of the obtained isopropanol solution of fluorine-containing polymer was added dropwise to 80 g of pure water at room temperature over about 10 minutes with stirring. Further a solution mixture of water/isopropanol of 80/20 % by mass was added thereto to adjust the total amount of composition to 200 g, and then filtration was carried out with a filter having an opening size of 0.2  $\mu\text{m}$  to obtain a homogeneous coating composition.

### EXAMPLE 10

(Preparation of coating composition)

A coating composition was obtained in the same manner as in Example 9 except that the fluorine-containing polymer obtained in Preparation Example 14 was used instead of the fluorine-containing polymer obtained in Preparation Example 13.

### EXAMPLE 11

(Preparation of coating composition)

A coating composition was obtained in the same manner as in Example 9 except that the fluorine-containing polymer obtained in Preparation Example 15 was used instead of the fluorine-containing polymer obtained in Preparation Example 13.

## EXAMPLE 12

(Preparation of coating composition)

A coating composition was obtained in the same manner as in Example 9 except that the fluorine-containing polymer obtained in Preparation Example 16 was used instead of the fluorine-containing polymer obtained in Preparation Example 13.

## EXPERIMENTAL EXAMPLE 17

(Measurement of a refractive index of a coating film)

A refractive index was measured using light of 193 nm wavelength in the same manner as in Experimental Example 10 after forming a coating film on a silicon wafer by using the coating compositions obtained in Examples 9 to 12.

The results are shown in Table 9.

## EXPERIMENTAL EXAMPLE 18

(Measurement of a dissolution rate of a coating film in a developing solution)

Production of a sample and measurement of a dissolution rate (nm/sec) in a developing solution by the quartz crystal oscillation method (QCM method) were carried out in the same manner as in Experimental Example 11 by using the respective coating compositions obtained in Examples 9 to 12.

The results are shown in Table 9.

## EXPERIMENTAL EXAMPLE 19

(Formation of laminated resist and measurement of reflectance)

Formation of photoresist layer:

A photoresist layer was formed by using a resist for ArF lithography in the same manner as in Example 1.

Formation of antireflection layer:

5           A laminated photoresist was obtained by forming, on the photoresist layer formed above, an antireflection layer in the same manner as in Example 1 by using the respective coating compositions obtained in Examples 9 to 12.

10           The reflectance of the obtained laminated photoresists was measured with light of 193 nm wavelength in the same manner as in Example 1.

The results are shown in Table 9.

TABLE 9

Coating composition	Ex. 9	Ex. 10	Ex. 11	Ex. 12
(A1) Fluorine-containing polymer	Prep. Ex. 13	Prep. Ex. 14	Prep. Ex. 15	Prep. Ex. 16
Number average molecular weight: Mn	50000	54000	39000	37000
Concentration of polymer (% by mass)	5.0	5.0	5.0	5.0
(B) Solvent				
Water	80	100	100	100
Isopropanol	20	0	0	0
Characteristics of coating film				
Refractive index (193 nm)	1.41	1.44	1.42	1.43
Dissolution rate in a developing solution (nm/sec)	1000 or more	1000 or more	1000 or more	1000 or more
Characteristics of laminated resist				
Reflectance (%)	1.17	1.65	1.33	1.50



## EXPERIMENTAL EXAMPLE 20

(Measurement of a dissolution rate of a coating film in water)

A dissolution rate (nm/sec) in water was measured in the manner mentioned below by the quartz crystal oscillation method (QCM method). The results are shown in Table 10.

Production of sample:

Compositions prepared in Examples 6 and 9 to 12 were applied on a 24 mm diameter quartz crystal oscillation panel coated with gold to make about 100 nm thick coating films.

10 Measurement of dissolution rate in water:

A coating film thickness is calculated by converting the number of oscillations of the quartz crystal oscillation panel.

The quartz oscillation panel produced above by coating the fluorine-containing polymer was dipped in pure water. After dipping of the panel, a change in a coating thickness was obtained from a change in the number of oscillations with the progress of time, and a dissolution rate per unit time (nm/sec) was calculated (Reference bulletin: Advances in Resist Technology and Proceedings of SPIE Vol. 4690, 904(2002)). The results are shown in Table 10.

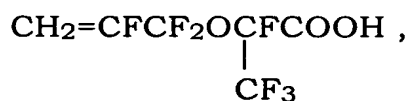
TABLE 10

Coating composition	Ex. 6	Ex. 9	Ex. 10	Ex. 11	Ex. 12
(A1) Fluorine-containing polymer	Prep. Ex. 12	Prep. Ex. 13	Prep. Ex. 14	Prep. Ex. 15	Prep. Ex. 16
Dissolution rate in water (nm/sec)	1000 or more	1000 or more	1000 or more	1000 or more	1000 or more

### PREPARATION EXAMPLE 17

(Synthesis of fluorine-containing polymer having -COOH group as the hydrophilic group Y)

Into a 300 ml autoclave were poured 20.0 g of  
5 perfluoro-(6,6-dihydro-2-trifluoromethyl-3-oxa-5-hexenoic acid):



10 80 g of CH<sub>3</sub>CCl<sub>2</sub>F and 0.2 g of dinormalpropylperoxy dicarbonate. After sufficiently replacing the inside of the autoclave with nitrogen, 20 g of tetrafluoroethylene was introduced. This autoclave was subjected to shaking on a 40°C hot water bath for 15 hours, and a colorless transparent solid was produced.

15 This solid dissolved in acetone was poured into n-hexane, followed by separation and vacuum drying, and 17.3 g of a colorless transparent polymer was obtained.

According to <sup>19</sup>F-NMR analysis, <sup>1</sup>H-NMR analysis and IR analysis, the polymer was a copolymer containing:

20



and tetrafluoroethylene in a percent by mole ratio of 67:33.

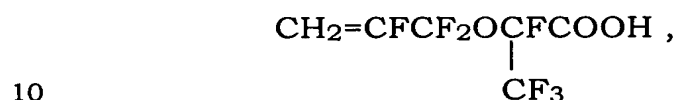
25 Also after methyl-esterification of the carboxyl group in the same manner as in Preparation Example 1, measurement by GPC was carried out. The number average molecular weight thereof was

61,000.

### PREPARATION EXAMPLE 18

(Synthesis of fluorine-containing polymer having -COOH group as the  
5 hydrophilic group Y)

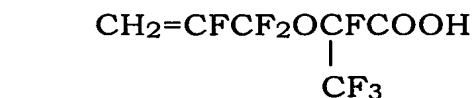
Into a 100 ml autoclave were poured 10.0 g of  
perfluoro-(6,6-dihydro-2-trifluoromethyl-3-oxa-5-hexenoic acid):



40 g of  $\text{CH}_3\text{CCl}_2\text{F}$  and 0.1 g of dinormalpropylperoxy dicarbonate.  
After sufficiently replacing the inside of the autoclave with nitrogen, 5 g  
of tetrafluoroethylene was introduced. This autoclave was subjected  
15 to shaking on a 40°C hot water bath for 15 hours, and a colorless  
transparent solid was produced.

This solid dissolved in acetone was poured into n-hexane,  
followed by separation and vacuum drying, and 7.5 g of a colorless  
transparent polymer was obtained.

20 According to  $^{19}\text{F}$ -NMR analysis,  $^1\text{H}$ -NMR analysis and IR  
analysis, the polymer was a copolymer containing:



and tetrafluoroethylene in a percent by mole ratio of 82:18.

Also after methyl-esterification of the carboxyl group in the

same manner as in Preparation Example 1, measurement by GPC was carried out. The number average molecular weight thereof was 46,000.

5

### EXAMPLE 13

(Preparation of coating composition)

The fluorine-containing polymer obtained in Preparation Example 17 was dissolved in an amount of 5 g in 24 g of isopropanol. The total amount of the obtained isopropanol solution of  
10 fluorine-containing polymer was added dropwise to 96 g of pure water at room temperature over about 10 minutes with stirring, followed by filtrating with a filter having an opening size of 0.2  $\mu\text{m}$  to obtain a homogeneous coating composition.

15

### EXAMPLE 14

(Preparation of coating composition)

A coating composition was obtained in the same manner as in Example 13 except that the fluorine-containing polymer obtained in Preparation Example 18 was used.

20

### EXPERIMENTAL EXAMPLE 21

(Measurement of a refractive index of a coating film)

A refractive index was measured using light of 193 nm wavelength in the same manner as in Experimental Example 10 after  
25 forming a coating film on a silicon wafer by using the coating compositions obtained in Examples 13 and 14.

The results are shown in Table 11.

## EXPERIMENTAL EXAMPLE 22

(Measurement of a dissolution rate of a coating film in a developing solution)

5 Production of a sample and measurement of a dissolution rate (nm/sec) in a developing solution by the quartz crystal oscillation method (QCM method) were carried out in the same manner as in Experimental Example 11 by using the respective coating compositions obtained in Examples 13 and 14.

The results are shown in Table 11.

10

## EXPERIMENTAL EXAMPLE 23

(Formation of laminated resist and measurement of reflectance)

Formation of photoresist layer:

15 A photoresist layer was formed by using a resist for ArF lithography in the same manner as in Example 1.

Formation of antireflection layer:

20 A laminated photoresist was obtained by forming, on the photoresist layer formed above, an antireflection layer in the same manner as in Example 1 by using the respective coating compositions obtained in Examples 13 and 14.

The reflectance of the obtained laminated photoresists was measured with light of 193 nm wavelength in the same manner as in Example 1.

The results are shown in Table 11.

TABLE 11

Coating composition	Ex. 13	Ex. 14
(A) Fluorine-containing polymer	Prep. Ex. 17	Prep. Ex. 18
Fluorine content	55.8	54.0
Number average molecular weight: Mn	61000	46000
Concentration of polymer (g/ 100 ml)	5.0	5.0
(B) Solvent		
Water	20	20
Isopropanol	80	80
Characteristics of coating film		
Refractive index	1.43	1.44
Dissolution rate in a developing solution	1000 or more	1000 or more
Characteristics of laminated resist		
Reflectance (%)	1.50	1.65

#### INDUSTRIAL APPLICABILITY

The present invention is featured especially by the  
5 fluorine-containing polymer (A) used for the antireflection layer (L2).  
When this fluorine-containing polymer (A) is present in the  
antireflection layer (L2) as main component, it is possible to reduce  
adverse effects on a resist pattern attributable to a standing wave effect  
arising in the case of using the photoresist layer (L1) alone and to a  
10 multiple reflection effect in patterning on a substrate having a step,  
and also it is possible to reduce a change of a pattern form attributable  
to an influence of outside atmosphere (an acidic or basic substance,  
water and the like in the air). As a result, the pattern form and  
dimensional accuracy are enhanced, and an ultrafine resist pattern  
15 being excellent in repeatability thereof can be formed.

The fluorine-containing polymer (A) used for the antireflection layer (L2) of the present invention can satisfy requirements for both of a low refractive index and water solubility or solubility in a developing solution (dissolution rate) though it has been  
5 difficult to satisfy the requirements. As a result, the polymer has performance adaptable to a conventional photolithography process, especially a developing process as before in addition to the above-mentioned effects in the pattern formation.

According to the present invention, since the antireflection  
10 layer of the laminated resist contains the fluorine-containing polymer containing hydrophilic group and having a high fluorine content, in a step for forming a laminated photoresist for lithography, particularly in lithography using ArF (193 nm) laser or F<sub>2</sub> laser as exposure light, it is possible to prevent lowering of dimensional accuracy of a pattern and  
15 decreasing of a dissolution rate in the developing step, which arise due to interference between the exposure light and the reflection light in the photoresist layer, and processability in micro fabrication can be improved.